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VFM

GAS, GASOLINE AND OIL ENGINES

By A. Frederick Collins

The Amateur Mechanic
How to Fly
The Home Handy Book
Keeping Up with Your Motor Car
The Book of Wireless
The Book of Stars
The Book of Magic
The Book of Electricity

D. Appleton & Company
Publishers New York

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GAS, GASOLINE AND OIL ENGINES

BY

A. FREDERICK COLLINS

AUTHOR OF "KEEPING UP WITH YOUR MOTOR CAR," "THE AMATEUR MECHANIC," "HOW TO FLY," ETC., ETC.

ILLUSTRATED

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TO
L. V. GOEBBELS

A WORD TO YOU

The watchword of the world is work!

Now work is done in two different ways and these are (1) By muscular strength and (2) by power developed by wind, water and heat.

As wind is uncertain and it is hard to convert it into useful power, about the only thing a windmill is good for is to pump water. Flowing water is steady enough but it is not often available, and, consequently, water wheels and turbines cannot be generally employed.

But heat, which is a product of chemical action, can be generated in small or large quantities any and everywhere, and steam and internal combustion engines run by it are built in all sizes. The internal combustion engine in which gas or liquid fuels are fired in the cylinder is the ideal engine for all purposes, as its initial cost is little, the fuel it burns is cheap, its upkeep is small, it is compact in size, light in weight and easy and safe to run.

In these days of labor-saving devices it is nothing short of a crime to pit your bodily strength against mechanical power, and this is especially true where the latter is produced by an internal combustion engine.

Again, as gas, gasoline and oil engines are rapidly displacing all other kinds of *prime movers* where small units are used and since they are already so extensively employed in the home, the shop, and on the farm, in the form of stationary, portable, tractor, motorcycle, motorboat, motorcar and airplane engines it behooves you to know how they work and how to run them.

And this is equally true whether you are a man or a woman, a boy or a girl, for it is only a question of time until you will find yourself face to face with one of them. If you are ignorant of how they are made and work you will, more than likely, go through the harrowing experiences and make the costly mistakes that countless others have made before you.

This is a great pity, for it is easy to know all about gas, gasoline and oil engines if you start right, and to do so all you need is to read this book through carefully.

A. Frederick Collins

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GAS, GASOLINE AND OIL ENGINES

GAS, GASOLINE AND OIL ENGINES

CHAPTER I

THE BEGINNINGS OF THE INTERNAL COMBUSTION ENGINE

Imagination is the ability to think new thoughts and invention is the power of the mind to shape these abstract thoughts into concrete things and make them useful or do useful work.

The history of the world shows that the human race has progressed through the imagination of only a few of its members and a study of inventors from Archimedes to our own Edison leads us to conclude that no single individual is capable of any great degree of imagining new forms but that it is the sum total of their creative faculties which has wrought the miracles of progress that we enjoy to-day.

It is a far cry from the modern high power guns that were used on the battle fronts of France to the equally high speed internal combustion engines employed to drive submarines and to develop power for more peaceful pursuits, but a glance at these two contrivances which are so unlike reveals the fact that they have sprung from the same stock, or perhaps *barrel* would be the more apt word, but it is true nevertheless.

The Coming of the Cannon.—The Chinese are given the credit of having discovered gunpowder and this was about the year 600 A.D. Some 600 years later the first gun to use gunpowder as the propelling force was invented in Bagdad, a city in Asiatic Turkey, and in 1234 the Chinese army under Genghis Khan used it for the first time in warfare. It is shown in *Fig. 1.*

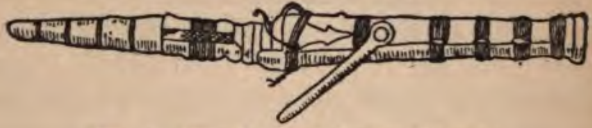


FIG. 1. THE EARLIEST KNOWN CANNON

The Earliest Glimmer of the Gas Engine.—Since gunpowder was one of the first prime forces to be discovered by man it was right in the logical sequence of things that it should have come in for a large amount of thought as a suitable power to harness up and use, and in this way save the energies of both man and beast.

These early inventors, if such they could be called, could see, with some stretch of their oriental imaginations to be sure, that the barrel of the cannon would make the cylinder of an engine and that the cannon ball would serve as a piston driven out by the force of the expanding gases which was given off by the burning powder. But there their imaginations ended and a celestial glimmering of the gas engine was as far as they ever got.

The Gas Engine Gets on Paper.—While the idea of converting an engine of destruction into an engine to pump water was flickering uncertainly in the minds of the Eastern philosophers, the uses of steam as a motive power had attracted the attention of Western inventors.

The first actual plans for an engine to be driven by gunpowder which would deliver continuous power were drawn up in 1678 by the Abbé Hautefeuille (pronounced *Hoté-fway*) who lived in France. Like the steam engine of Newcommen which was then under way the proposed gas engine of Hautefeuille was designed to pump water, for the scheme of changing the reciprocating motion of a piston into the rotary motion of a crank had as yet been scarcely thought of.

According to the plans of the Abbé the powder was to be burned in a cylinder having some water in it and, as the gases cooled off after burning, a *vacuum* would be formed when the piston would be forced up by the atmospheric pressure on the water. The principle of this engine was correct but the inventor did not try to build one.

The First Gas Engine to be Built.—Two years later, that is to say in 1680, Huygens, (pronounced

Haï-gens), a Dutchman, was the first to actually build a gas engine. It is shown in *Fig. 2.*

The inventor put the gunpowder in a little *ignition cup* in the bottom of the cylinder and then fired it by a flame through a touchhole. The explosion of the *fuel charge* drove the air in the cylinder out through leather valves and so formed a vacuum in it, and then the atmospheric pressure on the top of the piston forced it down in the cylinder.

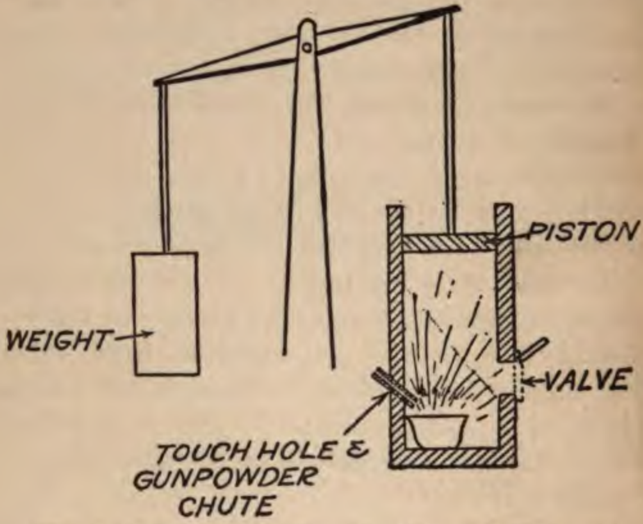


FIG. 2. HUYGENS', THE FIRST GAS ENGINE EVER BUILT

While this engine worked in a feeble way, the great trouble with it was that the valves could not be made air tight, and consequently the vacuum would not hold, hence Huygens' gas engine went by the board.

For over a century after Huygens had made this classic attempt, nothing further was done toward perfecting the gas engine. The reason for this long delay was because the steam engine had been steadily developed in England and it had proved a very satisfactory prime mover.

An American Makes the First Workable Gas Engine.—And now we come to a gas engine that was the first really practical one ever built up to the beginning of the nineteenth century, and the credit of it is due to Robert Street, an American.

He was granted a patent in 1794 for a gas cylinder and piston engine to work a pump. In this engine the bottom of the cylinder was heated and a few drops of turpentine were allowed to fall into it. When the turpentine evaporated it formed a vacuum in the cylinder and the atmospheric pressure on the piston forced it up.

An explosive mixture made by passing air over a sponge soaked in turpentine was admitted into the cylinder just before the piston moved up and the latter compressed it on its down stroke. A flame was then applied to the touchhole, which exploded the *fuel mixture,* as it is now called, and this drove the piston up. His engine is pictured in *Fig. 3.*

To Street is also due the credit of being the first to convert a liquid fuel into a gas and to make an explosive mixture by mixing it with air.

A Double Acting Gas Engine.—In the engines that have gone before you will have observed that the explosive force of the gas acted on one side of the piston only, and that is the way that all of the gas, gasoline, and oil engines are made to-day.

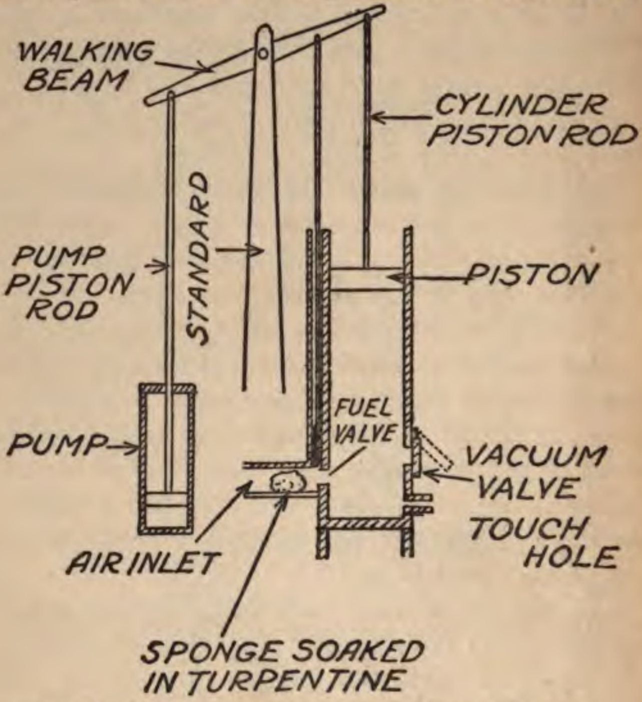


FIG. 3. STREET'S, THE FIRST GAS ENGINE TO WORK

In 1797 a Frenchman named Lebon took out a patent for a *double acting* gas engine in which the explosive fuel mixture was compressed by a compression pump and then admitted alternately on each side of the piston as steam is in an ordinary steam engine.

The piston rod was connected with a shaft and this worked the gas compressor pump. To fire the fuel mixture Lebon intended to use a spark set up by an electric machine which would also be driven by the shaft. Unfortunately the inventor was assassinated in 1804 and so his engine came to naught.

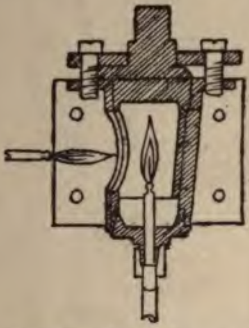


FIG. 4. BARNETT'S IMPROVED IGNITER

The Gas Engine Competes With the Steam Engine.—The first gas engine to be put to the practical test of pumping water was made by Samuel Brown, of London, in 1823. Like Hautefeuille's gas engine, his was of the vacuum type, and in the next ten years four of these engines were used in England for pumping water. Each engine could raise 300 gallons of water 15 feet high on 1 cubic foot of gas.

The Invention of an Improved Igniter.—William Barnett, also of England, got up in 1838 a double acting gas engine, but his fame rests on an *ignition cock* for firing the fuel mixture.

In this igniter, see *Fig. 4,* which was screwed to the head of the cylinder, two flames were used, one on the inside and the other on the outside of the cylinder; now when the force of the explosion put out the inside flame, a valve opened in the cock and it was again relit by the outside flame, which was always burning.

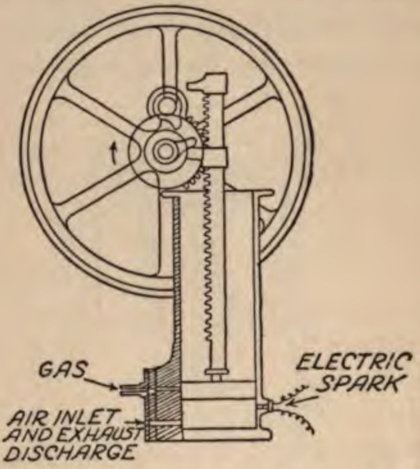


FIG. 5. BARSANTI AND MATTEUCCI'S ELECTRIC SPARK IGNITER

Then Came the Electric Spark.—It was Barsanti and Matteucci, of Italy, who first used the electric spark to ignite the fuel charge in the cylinder. This was in 1857, when electricity was getting pretty well out of its swaddling clothes. Their engine was also of special design, but it was not used afterward, and hence did not help along the state of the art. *Fig. 5* shows their igniter.

The Advent of the Commercial Gas Engine.—The workers along the line of the gas engine were busy now everywhere, but Lenoir, of France, designed and built, in 1860, the first gas engine that was really a commercial success.

There was nothing new or original about this gas engine of Lenoir's, but what he did was to work out every single part of it so carefully that when he built the engine it worked efficiently. His engine was very like the steam engine as it is built to-day, but, of course, with the addition of valves to admit the fuel mixture, and others to let the burnt gases escape. It is shown in *Fig. 6.*

In 1860 two of Lenoir's engines were built in Paris, one of six and the other of twenty horse power. According to descriptions published at that time both of these engines ran as smoothly and as silently as the best steam engines then in use.

An American Gasoline and Oil Engine.—In 1873 George Brayton began to build in the United States gasoline and oil engines which were better than any that had yet been produced.

The outstanding feature of the design of his engines was that the fuel mixture burned at a *constant pressure* instead of in a series of explosions.

The air was compressed in a cylinder by a piston which was connected to the beam of the engine, and this was admitted to the power cylinder together with a small quantity of oil on the upstroke of the piston in the compression cylinder. As the fuel mixture passed into the power cylinder it was ignited by a flame and thus the pressure was kept constant.

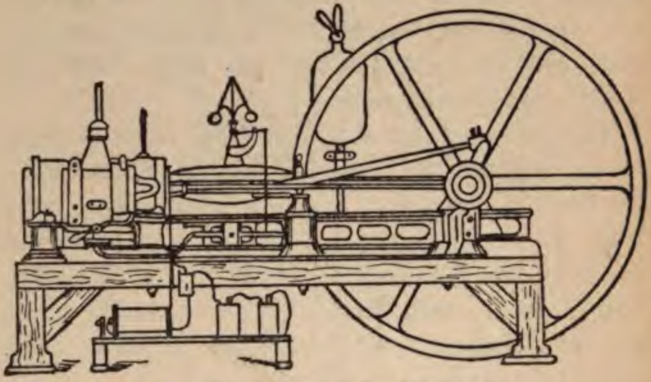


FIG. 6. LENOIR'S GAS ENGINE

To prevent the fuel mixture from backfiring from the power cylinder into the compression cylinder a piece of *wire gauze*[1] was placed in the intake pipe between them. As gas did not work well in Brayton's engine he used gasoline and oil. Air only was compressed in the compression tanks and just before it was passed into the cylinder of the engine it was

---

[1] If a piece of wire gauze is placed over a Bunsen burner the flame may be lighted either above or below the gauze but it will not pass through it. This is because the wires of the gauze are very good conductors of heat and prevent the gas on the other side from getting hot enough to light.

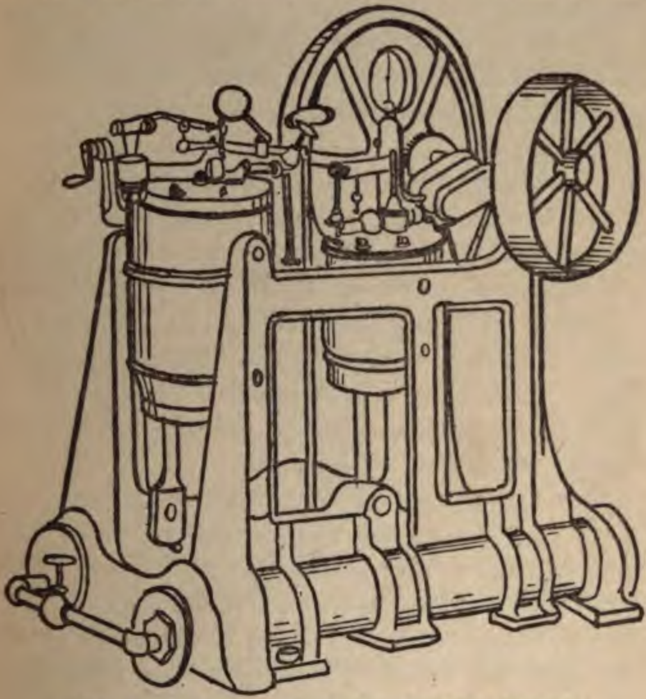


FIG. 7. BRAYTON'S GASOLINE AND OIL ENGINE

drawn across a sponge soaked in either gasoline or kerosene. See *Fig. 7.*

In the Brayton engine the inlet valve closed when the piston had traveled about one-half of its stroke and the expansion of the burning fuel mixture forced it on to the end in precisely the same manner as does the *latent heat* in steam. Brayton built a large number of these engines, and they were the best that had been made up to that time.

The Four Stroke Cycle Gas Engine.—As far back as 1682 Beau de Roches, of France, conceived and patented the scheme of making a *four stroke cycle*[1] gas engine, that is, an engine in which the first stroke would suck in the fuel mixture; the second stroke would compress it; the third stroke would be the power stroke, in virtue of the fuel mixture exploding, and the fourth stroke would push out the burnt gases.

Nearly 200 years later, that is, in the year of 1861, Nicholas August Otto, a German engineer, built a gas engine on the identical principles laid down by De Roches, and used a flame igniter quite like the one devised by Barnett.

This engine, see *Fig. 8,* is known as the *Otto four stroke cycle* gas engine, and was shown for the first time in public at the World's Fair in Paris, in 1867. The improved Otto engine was exhibited at the Centennial Exposition in 1876, and it worked so nicely and efficiently that over 30,000 of them were built and sold during the first ten years.

It was soon found that the four stroke cycle engine could be adapted equally as well to the use of liquid fuels, such as gasoline and kerosene, provided the proper devices were used to break up these liquids into a spray and mix them with the right amount of air.

---

[1] The term *four stroke cycle* means four successive strokes of the piston in which each one performs a different operation and the continued repetition of which makes the engine develop power.

When these small but important improvements had been made there grew up the great industries of building stationary, marine, motor car and, more recently, airplane engines.

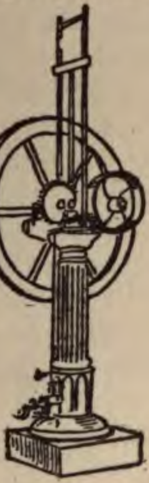


FIG. 8. THE FIRST COMMERCIAL OTTO GAS ENGINE

The Diesel Self-Ignition Oil Engine.—When air is compressed sufficiently, its temperature is raised high enough so that it will fire kerosene or other fuel oils if these are allowed to come in contact with it, and hence neither a flame nor a spark is needed to ignite the fuel charge.

Working on this principle, Rudolf Diesel, a German inventor, began to experiment with high compression engines in 1892. In his engine the air is compressed in the engine cylinder and, when it is under a high pressure and hot enough, the fuel oil is injected into it when the latter is fired and explodes.

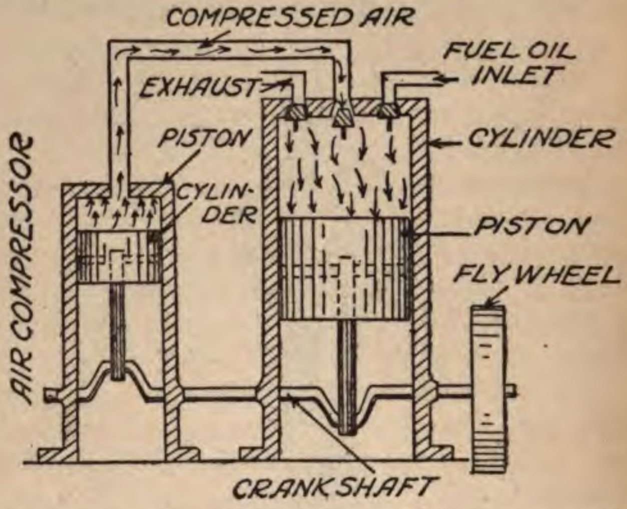


FIG. 9. SCHEMATIC DRAWING OF THE FIRST DIESEL SELF-IGNITING OIL ENGINE

Diesel engines are made in all sizes from 3 horse power, which is suitable for farm use, on up to those developing 2,000 horsepower. A diagram of the first Diesel engine is shown in *Fig. 9*.

CHAPTER II

THE INTERNAL COMBUSTION ENGINE SIMPLY EXPLAINED

To begin with, all engines in which the fuel is fired in the cylinders, or *internal combustion engines,* as gas, gasoline and oil engines are now generally called, work on the same fundamental principle, and that is by the expansive force of a gas acting on a piston in a cylinder.

How a Simple Gas Engine is Made.—To get a clear idea of how a gas engine works, let us start with a single cylinder engine and find out first how it is made.

Such a gas engine is shown in *Fig. 10,* and from this drawing you will see that it is built up of (1) a *cylinder* open at one end and which is fitted with (2) a *piston* that slides freely back and forth in it, (3) a *connecting rod,* one end of which is pivoted to the piston and the other end attached to the pin of (4) the *crankshaft,* and to the latter is fixed (5) the *flywheel,* which is not shown. Geared to the crankshaft is (6) a pair of *camshafts* with *cams* fixed on them so that they open the *inlet* and *exhaust* valves—they are closed by spiral springs at the proper instant, while another cam on one of the camshafts, see *Fig. 12, times* the electric spark, that is, it makes the electric spark take place at the right moment, and, finally, all of these parts are mounted on (7) a suitable frame.

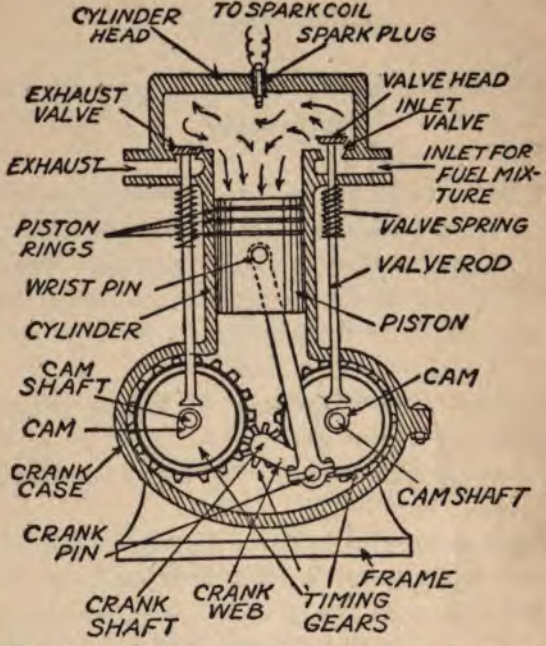


FIG. 10. CROSS SECTION OF A SIMPLE FOUR STROKE CYCLE GASOLINE ENGINE

The Inlet and Exhaust Valves.—These two valves are set in or near the closed end, or *head* of the cylinder. The inlet valve admits the fresh gas and air, or fuel mixture, as these are called when they are mixed and ready to be compressed in the cylinder.

The exhaust valve lets the waste products of combustion, or *burnt gases,* escape into the open air. Both the inlet and the exhaust valves must not only be opened at precisely the right time, but they must be held open exactly the right length of time and, as I have said above, this is the purpose of the cams on the camshaft.

The Igniter for Firing the Charge.—There are various schemes used for *igniting,* that is, firing the *fuel charge,* as the fuel mixture is called after it has been compressed in the cylinder.

For the purpose of explaining clearly how the gas engine works, we will suppose that the igniter is an electric one of the *jump-spark* type, in which a spark plug is screwed into the head of the cylinder with its business end inside. This will be described presently.

How a Simple Gas Engine Works.—*Two Stroke and Four Stroke Cycle Engines.*—The word *cycle* means that a certain series of operations repeat themselves.

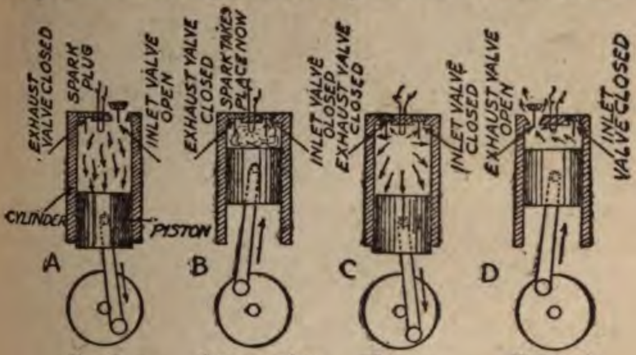
Now the cycle of a gas engine means the number of strokes the piston must make to perform the various functions which are necessary to run it. Some gas engines are made in which all of these operations take place when the piston makes two strokes and others when the piston makes four strokes.

The latter engine, or four stroke cycle engine, as it is called, which is a short way of saying that the engine makes four strokes to the cycle, is easier to understand than one that makes only two strokes to the cycle. This is because in the former each operation takes place separately and all of them above the piston, while in the latter two of the operations take place at the same time and part of them on one side of the piston and part on the other—that is, in the cylinder and in the crankcase. Hence, I shall explain how a four stroke cycle engine works first.

The Four Stroke Cycle Engine.—The strokes the piston makes in a four stroke cycle engine are (1) the *suction stroke*; (2) the *compression stroke*; (3) the *power or explosion stroke*, and (4) the *exhaust stroke*, and when they are done the cycle begins all over again.

The Suction Stroke.—The first down stroke of the piston is called the *suction stroke* because it sucks the gas and air into the cylinder; to do this of course the inlet valve must be open, as shown at A in *Fig. 11*, and the exhaust valve must be closed. And right here get this fixed in your mind—that for every stroke of the piston the crankshaft, and of course the flywheel on it, makes *one-half* of a complete revolution.

The Compression Stroke.—The moment the piston begins its up stroke the inlet valve closes and the exhaust valve must remain closed to keep the gas in the cylinder. This upward stroke of the piston compresses the fuel mixture and this gives it more force when it explodes. It is easy to see, now, why this is called the *compression stroke.* When the piston has completed its up stroke the crankshaft will have made another half-turn or *one complete* revolution in all. This stroke is shown at B.



Suction Stroke. Compression Stroke. Power Stroke. Exhaust Stroke.

FIG 11. SCHEMATIC DRAWING SHOWING HOW A FOUR STROKE CYCLE SINGLE CYLINDER ENGINE WORKS

A, B, C, and D represent the same cylinder and show what takes place during two revolutions of the crankshaft.

The Power Stroke.—When the piston is up to the head of the cylinder and the fuel mixture is compressed, it is then fired and explodes, or rather burns, for this is what it really does; the sudden force of the expanding gases drives the piston down and this stroke, which is the effective, or *power stroke,* see *C,* pushes the crankshaft around another half-turn, and this is the stroke that develops the power. During this stroke both the inlet and the exhaust valves stay closed.

The Exhaust Stroke.—The instant the power stroke is completed the exhaust valve opens and as the piston moves up it pushes the burnt gases out of the cylinder and into the open air. At the end of this stroke the exhaust valve closes, the inlet valve opens and the cycle of strokes begins all over again. The position of the valves, the piston and the crankshaft during the exhaust stroke is shown at D.

From the above you will see that there is only one power stroke, to every four strokes of the piston, or cycle of the engine, and as the crankshaft makes half a turn for each stroke of the piston it is evident that there are two revolutions of the crankshaft to every power stroke, which means that power is applied to the crankshaft in turning it around only one-quarter of the time.

How the Inlet and Exhaust Valves Work.—Since the inlet and exhaust valves open only once in every four strokes of the piston and since there are two revolutions of the crankshaft to every four strokes, it is clear that an eccentric, or another crank, on the crankshaft could not be used to open them, as these devices do to move the slide valve in a steam engine.

Instead, a *camshaft* is geared to the crankshaft with gears in the ratio of 2 to 1, that is, the gear on the camshaft has twice as many teeth on it as the one on the crankshaft with which it meshes. This *reduction gear* makes the camshaft turn only half as fast as the crankshaft, with the result that every time the camshaft makes a complete revolution, which is once in every four strokes, the valves are raised. When the cams have moved on past the valve rods the springs force the latter down and so close the valves which are fixed to them.

How the Electric Spark Igniter Works.—The simplest kind of a *jump-spark igniter* consists of (1) an *induction coil,* or *jump-spark coil* as it is called, which changes the *low pressure* current generated by a *dry battery* into a *high tension* current that will jump across an air-gap between two metal points about $\frac{1}{32}$ of an inch apart, which are set in a *spark-plug.*

The spark coil is connected to the spark-plug in the cylinder through a timing device, or *timer* as it is called. This device is simply a *make and break contact switch* which is worked by a cam on the camshaft, and this makes and breaks the electric circuit once in every four strokes of the piston at the instant when the charge must be fired. It is shown schematically in *Fig. 12.*

How the Engine is Made to Run Smooth.—As you quite likely know, every stroke of the piston of a steam engine is a power stroke and, as you have just seen, only one stroke in every four of the piston of a single cylinder four stroke cycle gas engine is a power stroke.

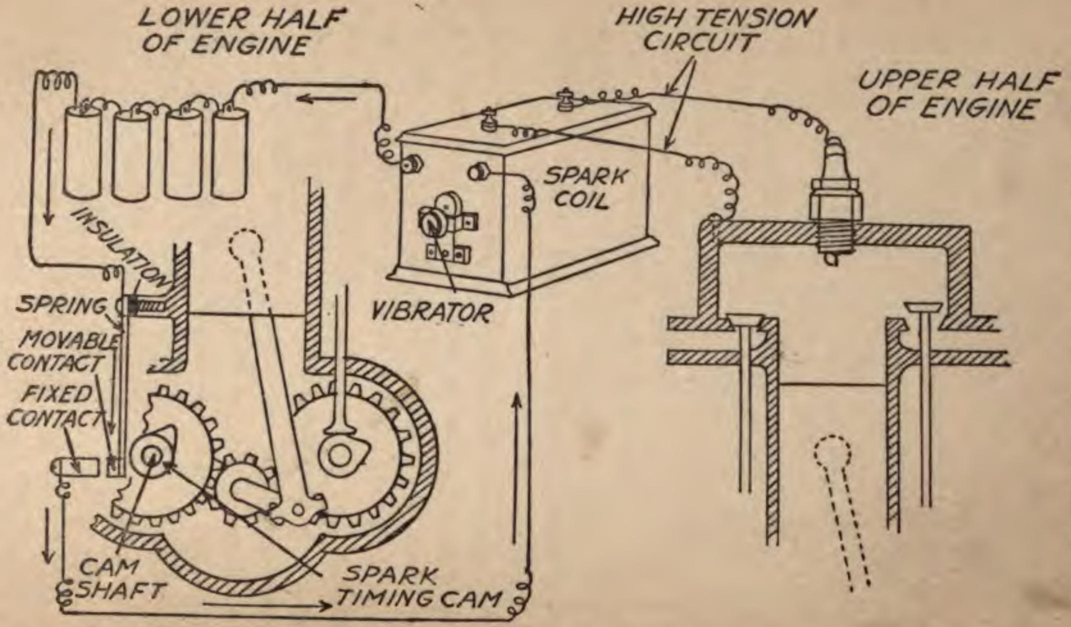


FIG. 12. SCHEMATIC DRAWING SHOWING A SIMPLE JUMP-SPARK IGNITION SYSTEM AND HOW IT IS TIMED

The result is the steam engine works smoothly and the gas engine has a tendency to run unevenly. Now there are three ways to make a gas engine run with a steadiness comparable to that of a steam engine, and these are (1) by putting one, or better, two heavy flywheels on the crankshaft; (2) by fitting a governor to it, and (3) by connecting up the pistons of two, often four, sometimes eight, and occasionally twelve cylinders to a single crankshaft, and some engines adopt all of these expedients to get the best result.

What the Flywheel Does.—The flywheel as it rotates gathers energy and when it is turning fast enough its *inertia*[1] tends to keep up the speed of the engine and to make it more nearly uniform.

How the Governor Works.—The governor of a gas engine works on the same principle as that of a steam engine. The simplest type, see *Fig. 13,* is called a *flyball governor,* and it consists of a vertical shaft, called a *governor shaft,* geared to the camshaft which makes it revolve at a goodly speed.

A pair of arms, each of which carries a ball on its free end, is pivoted to a support while the upper ends of the arms press on the top of the shaft. A sleeve is fixed to the shaft and a lever with a fork at one end sets in a groove in the sleeve and this opens and closes the gas valve which admits the fuel into the cylinder.

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[1] When a body is at rest it tends to remain so and when in motion to keep on going, and this property of matter is called *inertia.*

As the engine increases its speed the balls revolve faster around the shaft and fly farther and ever farther apart. In so doing the arms press down on the shaft and, as the sleeve moves down with it, it works the forked lever and this in turn cuts off the supply of gas; the engine then slows down, the balls fall and the gas valve is again opened.

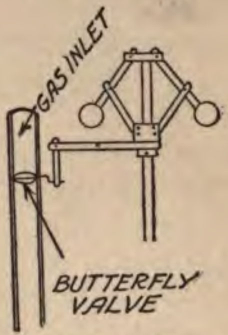

FIG. 13. A SIMPLE FLYBALL THROTTLING GOVERNOR

The Purpose of Multi-Cylinders.—There are two ways open to get a power stroke oftener than once in every two revolutions, and these are (1) to connect two or more pistons to a single crankshaft and (2) to use a two stroke cycle engine which has one or more cylinders.

Where *multi-cylinders* are used the pistons are connected to the crankshaft in such a way that the power strokes will be delivered in succession, and this has the effect, if there are enough cylinders, of developing practically continuous power like the piston of a steam engine. The way in which four pistons of a four stroke cycle engine are connected to the crankshaft is shown in *Fig. 14*.

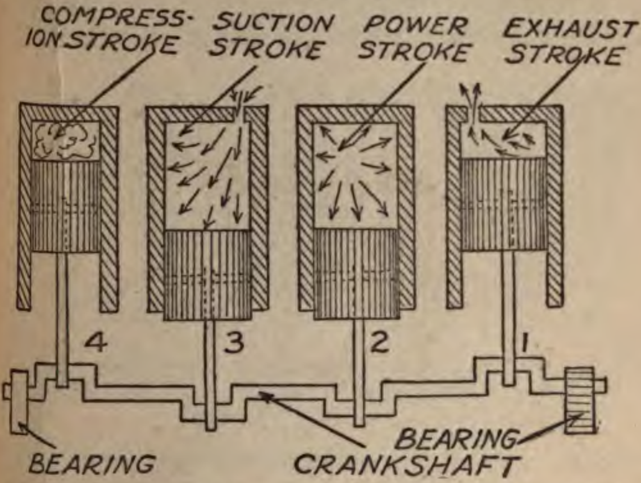

FIG. 14. SCHEMATIC DRAWING SHOWING HOW A FOUR CYLINDER, FOUR STROKE CYCLE ENGINE IS CONNECTED TO THE CRANKSHAFT

The order in which the cylinders are fired is 1, 2, 4, 3.

Where four cylinders are used there is a power stroke for each half-turn of the crankshaft, and the only breaks in the continuity of the power developed is at the end of each power stroke and the beginning of the next one, and this is the equivalent of the power delivered by a single cylinder steam engine.

When six or more cylinders are used the gaps between the strokes are bridged, and hence the more cylinders the smoother the engine will run. The way in which the valves are timed in a four stroke cycle, four cylinder engine is shown in *Fig. 15.*

A Simple Two Port, Two Stroke Cycle Engine.—In the two stroke cycle engine every other stroke of the piston is a power stroke, and this makes it more powerful for its size, and it runs smoother than a four stroke cycle engine having the same number of cylinders. Further it is simpler in construction than a four stroke cycle engine, but on the other hand it heats up more and is not as efficient as the latter. A clear cross section view of it is shown in *Fig. 16.*

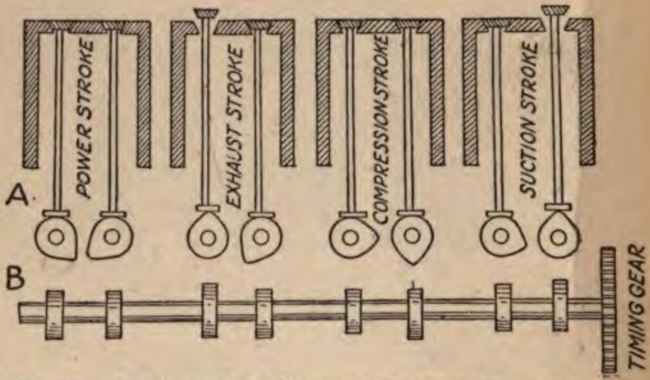

FIG. 15. (A) SCHEMATIC DRAWING SHOWING HOW THE CAMS OF A FOUR STROKE CYCLE ENGINE ARE SET TO TIME AND WORK THE VALVES. (B) THE CAMS AS THEY ARE SET ON THE CAMSHAFT

The way it works is like this: On the first up stroke of the piston, the fuel mixture is sucked through the intake pipe, which has a valve in it, into the crankcase, as shown at A in *Fig. 17.* As the piston moves down the fuel mixture is compressed in the crankcase, but just as the piston reaches the end of its down stroke it slides across two *ports* and opens them. One of these ports connects the cylinder with the crankcase and the other one, which is the exhaust port, leads to the open air, as shown at B.

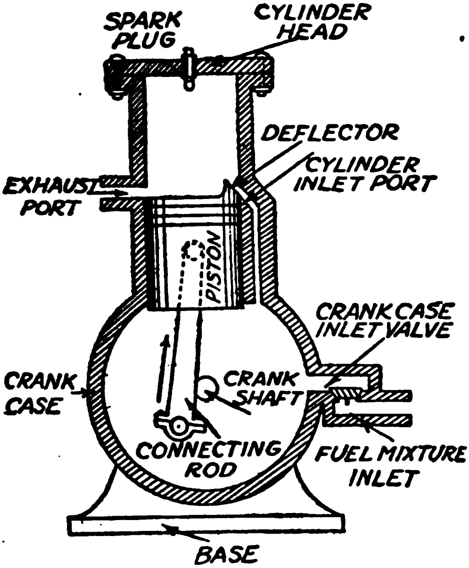

FIG 16. HOW A SIMPLE TWO PORT, TWO STROKE CYCLE ENGINE IS MADE

The compressed gas in the crankcase now rushes into the cylinder and at the same time it drives out the burnt gases but while these two operations take place in the cylinder at the same time a little of the latter will remain behind and mix with the fresh fuel charge.

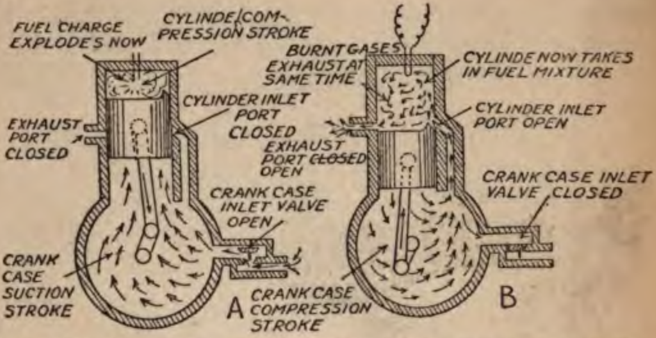
FUEL CHARGE EXPLODES NOW
CYLINDER COMPRESSION STROKE
EXHAUST PORT CLOSED
CYLINDER INLET PORT CLOSED
CRANK CASE INLET VALVE OPEN
CRANK CASE SUCTION STROKE
A
CRANK CASE COMPRESSION STROKE
BURNT GASES EXHAUST AT SAME TIME
CYLINDE NOW TAKES IN FUEL MIXTURE
CYLINDER INLET PORT OPEN
EXHAUST PORT ~~CLOSED~~ OPEN
CRANK CASE INLET VALVE CLOSED
B

Fig. 17. Schematic Drawing Showing How a Two Port, Two Stroke Cycle, Single Cylinder Engine Works

A and B represent the same cylinder and show what takes place during *one* revolution of the crankshaft.

First Stroke (Up)	Second Stroke (Down)
(a) Crankcase Suction Stroke	(a) Power Stroke
(b) Cylinder Compression Stroke	(b) Crankcase Compression Stroke
(c) Fuel Charge Fired	(c) Cylinder Admits Fuel Mixture and Exhausts Burnt Gases

On the up stroke of the piston the fuel charge is further compressed and when the piston reaches the end of its compression stroke the charge is ignited and a power stroke takes place.

A Three Port, Two Stroke Cycle Engine.—In the three port engine no check valve is used between the carburetor, fuel nozzle and the crankcase but, instead, a third port leads from the former to the latter, and this is opened by the piston on the compression stroke that takes place in the cylinder and closed on the power stroke. *Fig. 18* is a clear cross-section view of it.

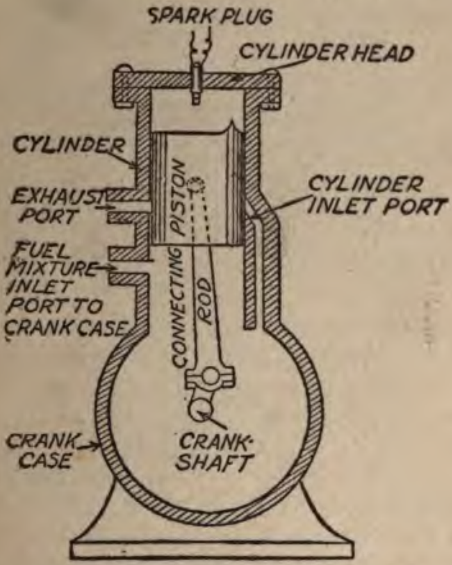

FIG. 18. HOW A SIMPLE THREE PORT, THREE STROKE CYCLE ENGINE IS MADE

This arrangement makes the three port engine work a little differently from that of a two port engine. In the three port engine when the piston goes up it closes the cylinder inlet port, as shown at A in *Fig. 19,* and the suction of the piston increases the vacuum inside of the crankcase until the open end of the piston slides by and opens the third or inlet port when the fuel mixture from the carburetor or nozzle rushes into the crankcase and fills it.

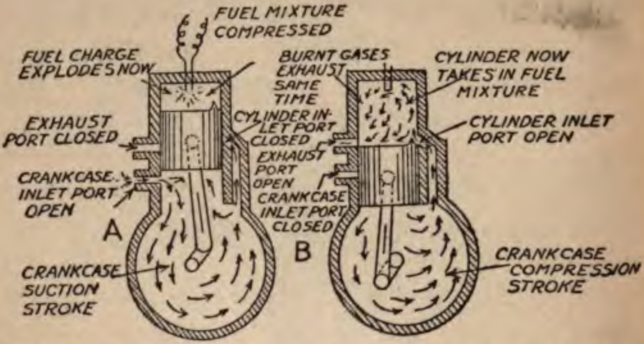
FUEL MIXTURE COMPRESSED
FUEL CHARGE EXPLODES NOW
EXHAUST PORT CLOSED
CRANKCASE INLET PORT OPEN
A
CRANKCASE SUCTION STROKE
BURNT GASES EXHAUST SAME TIME
CYLINDER INLET PORT CLOSED
EXHAUST PORT OPEN
CRANKCASE INLET PORT CLOSED
B
CYLINDER NOW TAKES IN FUEL MIXTURE
CYLINDER INLET PORT OPEN
CRANKCASE COMPRESSION STROKE

Fig. 19. Schematic Drawing Showing How a Three Port, Two Cycle Single Cylinder Engine Works

A and B represent the same cylinder and show what takes place during *one* revolution of the crankshaft.

First Stroke (Up)	Second Stroke (Down)
(a) Crankcase Suction Stroke	(a) Power Stroke
(b) Cylinder Compression Stroke	(b) Cylinder Inlet Port Admits Fuel Mixture
(c) Fuel Charge Fired	(c) Burnt Gases Escape

When the piston makes its down or power stroke, as shown at B, it again covers the third inlet port and the fuel mixture is compressed in the crankcase. On reaching its lowest *dead center,* that is, its lowest point, the piston opens the duct, or passage, between the crankcase and the cylinder when the compressed fuel mixture in the crankcase rushes into the cylinder above.

How a Diesel Engine Works.—The salient feature of this engine is that it does not use an igniter of any kind to fire the fuel charge, but it does this by simply compressing air in the cylinder.

It is a well-known fact that when air is compressed its temperature is raised. As a simple illustration, if you will take a toy pop-gun, plug up its free end tight and then compress the air in it by pushing the piston down quick and hard, you will find that the barrel gets quite hot. Another and more striking experiment of the same kind is to ignite a bit of tinder, or a pellet of cotton, soaked in *ether* by means of a simple apparatus called a *fire-syringe.*[1]

Now this principle relating to pressure and heat is taken advantage of in the Diesel engine, and in this way a high enough temperature is obtained to fire the fuel charge which is injected into the compressed air charge in the cylinder. This scheme of self-ignition does away with ignition devices entirely, and at the same time the cylinder is kept at such a high temperature that the heaviest fuel oils are instantly converted into gases that burn well when mixed with air. Diesel engines are made in both the two stroke and the four stroke cycle types.

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[1] You will find a description of this experiment in almost any elementary text-book on *Physics.*

How a Semi-Diesel Engine Works.—The semi-Diesel engine does not require as high a compression as the straight Diesel, but, like the latter, it burns the heaviest fuel oils and does away with complicated electric ignition devices.

The only difference between the semi-Diesel and a straight Diesel engine is that the former has a *hot ball* or *bonnet,* set in the head of the cylinder, and this must be heated by a blow-torch before the engine is started.

On the up stroke the piston compresses only air in the cylinder and when the end of this stroke is nearly reached the fuel is injected against the red-hot walls of the ball or bonnet, when it is instantly changed into gases and explodes. Semi-Diesel engines are made in both the two and four stroke cycle types and a further discussion about them will be found in Chapter VI.

How to Figure the Horse Power of an Engine.—The horsepower of any internal combustion engine regardless of the kind of fuel it burns can be easily found by using the following formulae:

For a Four Stroke Cycle Engine.

$$\text{H. P.} = \frac{D^2 \times N}{2.5}$$

where H. P. is the horsepower and is what you want to find,

D^2 is the diameter of the bore of the cylinder, and this you square,
N is the number of cylinders, and
2.5 is a constant.

For a Two Stroke Cycle Engine.

$$H. P. = \frac{D^2 \times N}{1.5}$$

These symbols represent the same quantities as hose above given.

CHAPTER III

THE EFFICIENT GAS ENGINE

For stationary work, where natural or artificial gas can be had, the gas engine is the most efficient kind of an internal combustion engine you can use.

Not only is it the most efficient, but since there is a constant supply of fuel at hand and it can be used directly in the cylinder of the engine without any intervening apparatus it is safer and less troublesome than an engine using liquid fuels.

Gas engines in all sizes from 1 to 150 horsepower are made with single cylinders, and from 150 to 1500 horsepower they are made with two cylinders, or twin cylinders, as they are called. Engines of from 1 to 8 horsepower have vertical cylinders, while they are made from 4 to 2000 horsepower with horizontal cylinders.

The Parts of a Gas Engine.—In a gas engine of either the vertical or horizontal type there are eleven principal parts, and these are (1) the *frame;* (2) the *cylinder;* (3) the *air valve;* (4) the *gas valve;* (5) the *exhaust valve;* (6) the *piston;* (7) the *connecting rod;* (8) the *crankshaft;* (9) the *camshaft*[1]; (10) the *igniter;* and (11) the *governor.*

The Frame.—This is made of cast iron and on it rests the cylinder and crankshaft bearings. It must be heavy enough to prevent vibration and to keep the bearings from getting out of line. It is shown at A in *Fig. 20.*

The Cylinder and Water Jacket.—The cylinder (see B) has a water jacket C fitted around it so that water can be made to circulate between them. The cylinder has a *ground bore,* that is, it is ground out with an emery wheel instead of being bored out, and this permits the piston to fit much closer and of course this makes the compression better.

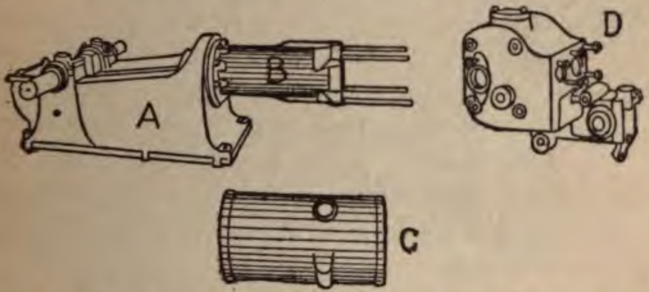

FIG. 20—A, B, C AND D. THE FRAME, CYLINDER, WATER JACKET AND CYLINDER HEAD OF AN OTTO GAS ENGINE

The Cylinder Head.—This is also an iron casting and all of the valves are fitted in it and the igniter is mounted on it. The combustion of the fuel charge takes place in it and, hence, this part is called the *combustion chamber*. It is shown at D.

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[1] A camshaft is usually called a gearshaft when on a stationary gas or gasoline engine.

The Air, Gas and Exhaust Valves.—These valves are called *poppet valves,* and are kept closed by spiral springs. They have flat, steel heads with beveled edges so that they will *seat,* that is fit tight, into the inlet and exhaust ports of the cylinder.

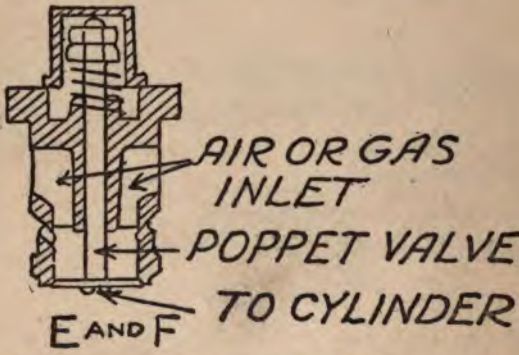
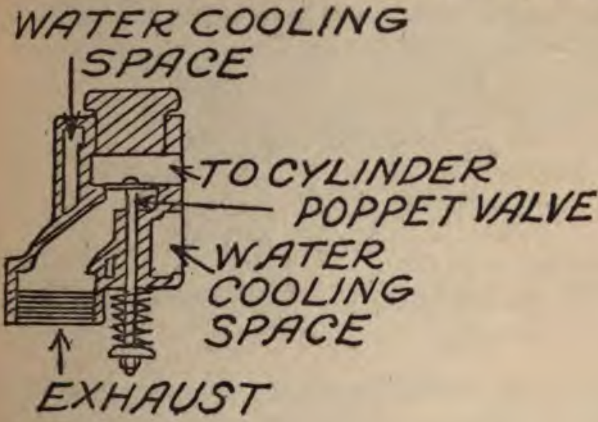


FIG. 20—E AND F. THE AIR INLET VALVE AND THE GAS VALVE ARE MADE AND WORK THE SAME

The Air Inlet Valve.—The air and gas are taken into the cylinder through separate valves, when they mix inside of it to form the *fuel mixture.* The *air valve* is an *automatic suction valve,* that is, it is a valve that is opened by the suction of the piston at the same time that the gas inlet valve is opened, and it is kept closed during the other strokes by the spiral spring and the internal pressure on it. It is shown at E.

The Gas Valve.—This valve sets close to the air valve in the cylinder head, and it admits the gas into the cylinder at the same time the air is taken in by the suction stroke. It is opened at the right time by a cam working on the camshaft. All that is needed is to connect a gas pipe, with a gas cock in it, to regulate the supply of gas to the valve, and turn on the gas. It is the same as the air valve and is shown at F.



G

FIG. 20—G. THE EXHAUST VALVE

The Exhaust Valve.—As the burnt gases exhaust through this valve it gets very hot and it should therefore be *water cooled.* It is *timed* to open by and is worked from the camshaft by a cam and an exhaust lever. It is shown at G.

The Piston and Piston Rings.—The piston is made of the same kind of iron as the cylinder and is accurately ground to fit it.

Different from a steam engine, the piston of a gas engine is long and hollow, with one end closed and the other open; again, instead of being *packed* with hemp or asbestos it has grooves cut in it and *packing rings,* or *piston rings,* as they are called, are slipped into them. These rings are also of iron and make the piston fit so closely to the cylinder, that the fuel mixture cannot leak by it.

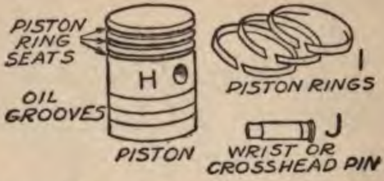


FIG. 20—H, I, AND J. THE PISTON, PISTON RINGS AND CROSSHEAD PIN

The piston has a crosshead pin, called a *wrist pin,* set across its center and on this the small end of the connecting rod is secured. The piston and piston rings are illustrated at H and I, and the wrist pin at J.

The Connecting Rod.—Since the piston is long no piston rod, guides and crosshead such as are used in a steam engine are required, hence the piston is usually coupled direct to the crankshaft with a connecting rod. How it is made is shown at K.

The Crankshaft and Flywheels.—This shaft, see M, changes the reciprocating motion of the connecting rod into rotary motion. It usually carries two flywheels, one on each end, and these are made very heavy, which help to keep the speed uniform. The crankshaft also has a pulley and a spiral, or worm gear on it and the latter meshes with another spiral gear on the camshaft.

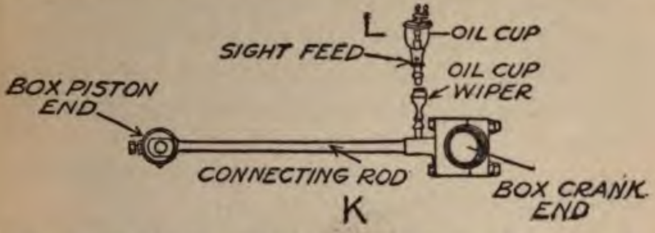


Fig. 20—K and L. The Connecting Rod with Wiper Oil Feed

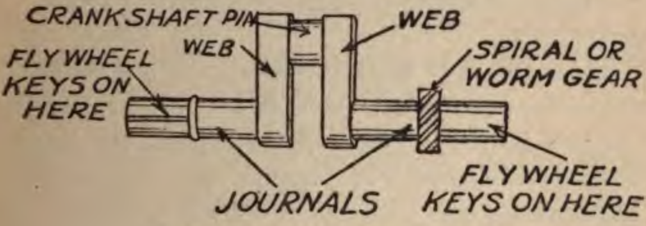


Fig. 20—M. The Crankshaft

The Cam or *Gearshaft.*—In vertical and some horizontal engines the valves and igniter for firing the fuel charge are worked by a *reciprocating rod,* while in other horizontal engines the valves and igniter are operated by a *rotating camshaft.* It is shown at N.

This shaft is driven by the crankshaft through a pair of *spur* or *spiral gears.* A bevel gear is keyed to the shaft which drives the governor, and the cams on it work the gas and exhaust valves and the igniter.

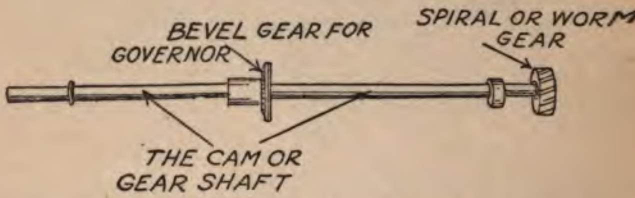


FIG. 20—N. THE CAM, OR GEAR SHAFT

A horizontal Otto gas engine assembled is shown in *Fig. 21.*

About the Gas Supply.—Since the gas does not flow into the cylinder in a steady stream, but by the intermittent suction of the piston, the supply pipe must be sufficiently large to deliver enough gas for each charge.

Not only this, but a rubber bag, as shown in *Fig. 22,* is connected in between the gas supply pipe and the gas inlet valve of the engine. This bag acts as a reservoir and supplies all the gas that is needed for each fuel charge. For a small engine the bag should be protected by a wooden box, but for a large engine it should be enclosed in an iron casing.

Kinds of Ignition Schemes.—There are two kinds of ignition schemes used on gas engines to fire the fuel charge and these are (1) the *hot tube igniter* and (2) *electric ignition systems.*

The Hot Tube Igniter.—This is a simple, but it is not a very safe, ignition scheme. It consists of a steel tube open at one end and closed at the other; the open end is fixed in the cylinder near the head so that the fuel charge can reach it, and it is kept white hot by the flame of a Bunsen burner.

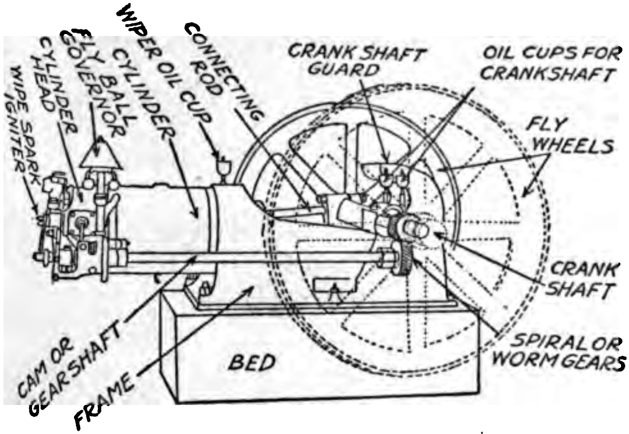


FIG. 21. A HORIZONTAL OTTO GAS ENGINE COMPLETE

The walls of the tube are about $\frac{1}{16}$ inch thick, it has an outside diameter of about ½ an inch, and a length of about 5 inches. An iron tube 1½ inches in diameter and lined with asbestos sets around the hot tube to prevent the loss of heat; a lot of little air holes are drilled near the lower end of the iron tube and just above them a ½-inch pipe is screwed into it. This pipe is connected to a gas supply and this provides the flame to heat the tube. The whole scheme is shown in cross-section in *Fig. 23.*

The way the hot-tube works is like this: the instant the fuel mixture is compressed either an ignition valve is opened by a cam on the camshaft or the piston slides off of a port or hole which opens into the tube. The fuel charge then rushes into the incandescent tube when it is ignited, and the flame sweeps back into the cylinder and fires the charge. This hot tube igniter is a very decided improvement over Barnett's ignition cock, which I described in the first chapter.

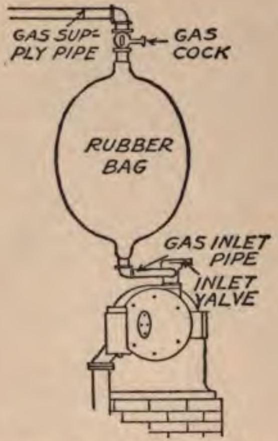


FIG. 22. HOW THE GAS IS SUPPLIED TO THE ENGINE

Kinds of Electric Igniters.—There are two kinds of electric ignition systems used on gas engines, and these are (1) the *wipe spark,* or *make and break system* and (2) the *jump-spark system.*

Wipe Spark Igniters.—*The Battery and Spark Coil System.*—Likewise, there are two kinds of *wipe spark igniters* and these are (1) *the battery and spark coil system* and (2) *the magneto system.*

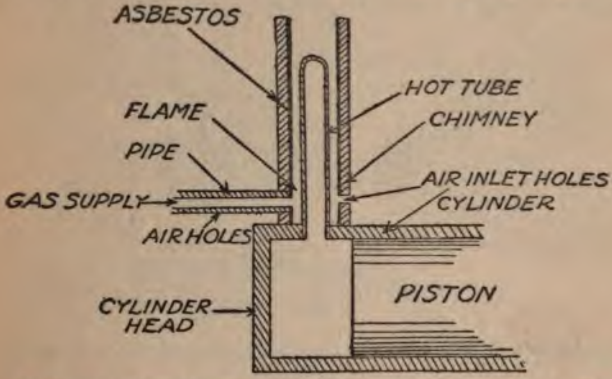


FIG. 23. THE CONSTRUCTION OF A HOT TUBE IGNITER

Where a battery and spark coil is used the system is formed of four chief parts, namely, (1) the *battery,* (2) the *spark-coil,* (3) the *igniter mechanism,* and (4) the *wipe spark electrodes.*

The battery consists of half a dozen *dry, Edison-Lalande* or *storage cells.* The spark-coil, or *kick-coil* as it is called, is the kind used for lighting gas jets, that is, it is made up of a *single coil* of No. 16 or 18 insulated copper wire wound on a soft iron *core.*

The purpose of this coil is to raise the *voltage,* that is, the *pressure* of the battery current, so that when the circuit is broken it will give a good hot spark. This the coil does by the action of the current on itself as it flows through the adjacent turns of wire, and the higher tension current thus set up is called the *extra current.*

The wipe spark electrodes consist of a *fixed contact point* and a *movable contact point,* both of which are mounted on a flange; this is bolted to the head of the cylinder so that the electrodes are inside of the latter and the binding posts of the electrodes and the lever which works the movable electrode are outside of the cylinder head. The fixed and movable electrodes are well insulated from each other so that the current will not *short circuit.* The scheme is shown in *Fig. 24.*

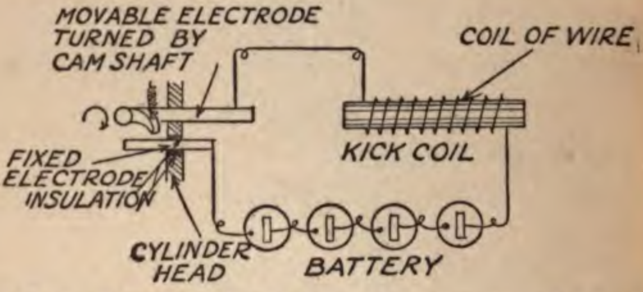


Fig. 24. The Wipe Spark Igniter Operated by a Battery and a Kick Coil

The igniter mechanism is simply a lever worked by the camshaft which presses against the interruptor lever with the movable electrode on it until the latter makes contact with the fixed electrode and the circuit is then closed.

At the right instant the pressure on the movable electrode lever is released and a spring makes it snap back, thus *wiping* the fixed electrode and breaking the contact between them, and this makes a spark. An Otto igniter is shown at A and B in *Fig. 25,* and the mechanism working it is shown at A and B in *Fig. 26.*

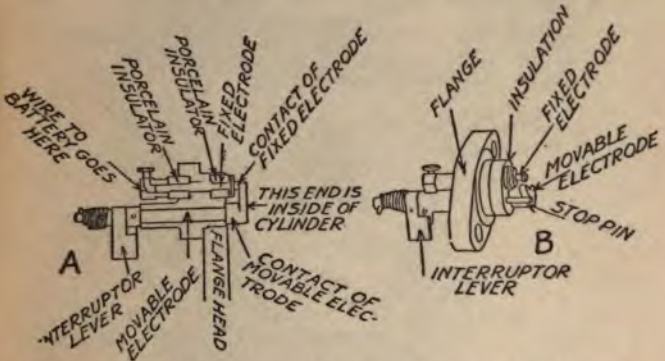


FIG. 25. THE MECHANISM OF THE WIPE SPARK IGNITER

A, Cross Section of the Wipe Spark Igniter. B, The Igniter Ready to Use.

Low Tension Magneto System.—A *magneto electric machine,* or just *magneto* for short, is a machine which generates electric alternating currents.

There are two kinds of *low tension magnetos* made,

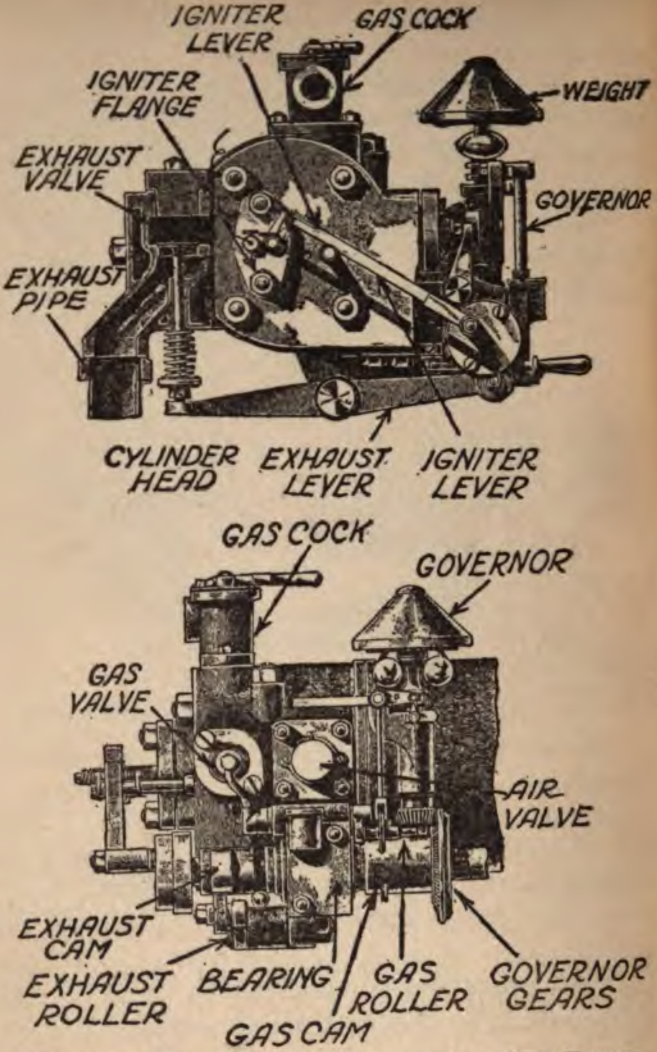


FIG. 26. THE WIPE SPARK IGNITER ON AN OTTO ENGINE

A, End View of Cylinder Head Showing Mechanism of Wipe Spark Igniter and Exhaust Valve. B, Side View of Cylinder Head Showing Mechanism of Wipe Spark Igniter and Governor Control of Gas Inlet Valve.

and these are used for generating currents for wipe spark igniters, as they are far less troublesome than the battery and spark-coil system. Now the two types of low tension magnetos are (1) the rotating magneto and (2) the oscillating magneto.

The Low Tension Rotating Magneto.—A magneto of this kind is built up of two main parts and these are (1) the *field magnet* and (2) the *armature*.

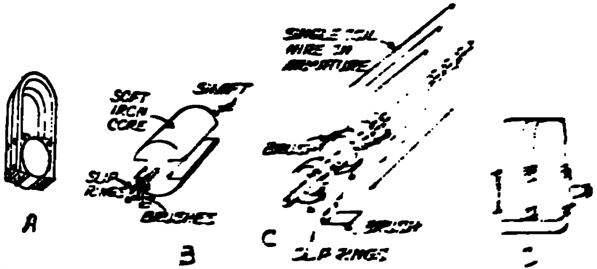


FIG. 27. THE LOW TENSION ROTATING ARMATURE MAGNETO. A, Permanent Field Magnet. B, The Armature Core. C, Single Coil of Wire Wound on the Armature. D, The Magneto Complete.

The field magnet is merely a powerful permanent horseshoe magnet, as shown at A in Fig. 27, and the armature is a cylinder of soft iron with grooves cut lengthwise in the opposite sides of it and having a shaft through it, as shown in B.

A single coil of fine insulated wire is wound in the grooves of the armature and the ends are connected to brass collector rings, called slip-rings, on the shaft, see B and C, but which are insulated from it and from each other. The shaft runs in a pair of bearings so that the armature can revolve freely between the poles of the magnet. A strip of copper, called a *brush,* presses on each one of the sliprings and a wire leads off from the fixed end of each one of the brushes, as at C. The magneto complete is shown at D.

If the armature is rapidly rotated low tension electric currents will be set up in the coil of wire on it by the magnet and these will flow to the sliprings, where they will be taken off by the brushes; if now the ends of the wires are connected together *low tension,* that is, *low pressure,* currents will flow through the circuit thus formed, but when it is used to produce sparks the wires are connected to the fixed and movable electrodes.

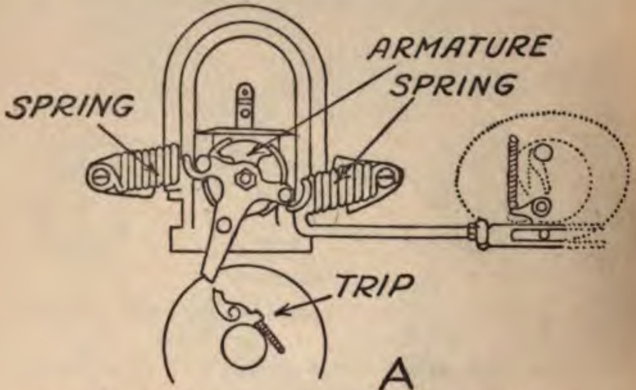


FIG. 28—A. A LOW TENSION OSCILLATING MAGNETO
A, The Control Mechanism of a Low Tension Magneto.

The Low Tension Oscillating Magneto.—The term *scillating magneto* means that the armature *oscil-tes,* that is, turns to and fro through a small arc nstead of rotating continuously as in the magneto ust described.

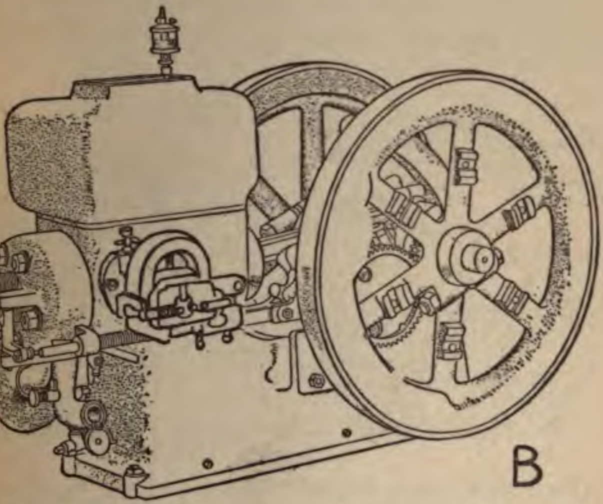


FIG. 28—B. A LOW TENSION OSCILLATING MAGNETO
B, The Oscillating Magneto on a Gas Engine.

This rocking motion is accomplished by an arm that pushes the armature back a few degrees, when it is tripped by a lever and is then suddenly pulled around by a pair of powerful spiral springs. The whole scheme is shown at A and B in *Fig. 28.* This type of magneto is better than a rotating magneto only in that it is much easier to start the engine.

Jump Spark Igniters.—This type of ignition apparatus is largely used on gas engines. There are two kinds of jump spark systems in vogue, and these are (1) the *battery and jump spark coil* system, and (2) the *high tension magneto system.*

The Jump Spark Coil System.—This is formed of (1) a *dry, Edison-Lalande* or a *storage battery;* (2) an *induction coil,* or *jump spark coil* as it is called; (3) a *timer,* and (4) a *spark-plug.*

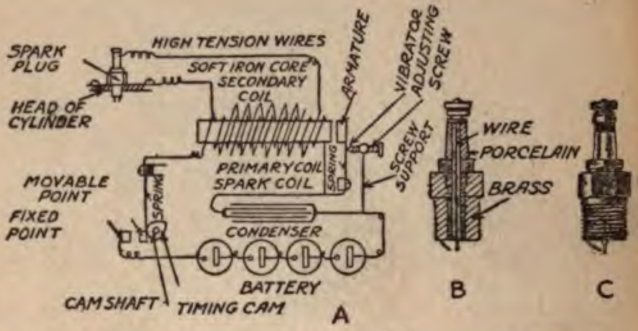
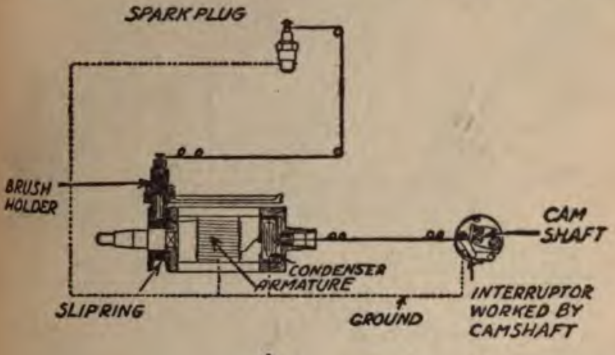


Fig. 29. Wiring Diagram of a High Tension Jump Spark Coil System

(See Fig. 12 for a Schematic Drawing of this System.)

The jump-spark coil is built up of *two coils of wire,* the first of which is of heavy insulated wire, called the *primary coil,* and this is wound on a soft iron core, while on the *primary coil,* but insulated from it, is wound a coil of fine wire called the *secondary coil.* An *interruptor,* generally called a *vibrator,* is worked by the core of the coil and this makes and breaks the primary circuit several hundred times a minute. A diagram of the battery and jump spark coil system is shown at A in *Fig. 29*.

Now when a rapidly interrupted battery current flows through the primary coil it sets up *high tension* currents in the secondary coil, and the pressure of these currents is high enough so that, if the ends of the secondary coil are separated a distance of ¼ of an inch, a spark will jump between them.



A

FIG. 30.—A. WIRING DIAGRAM OF A HIGH TENSION MAGNETO AND INTERRUPTOR FOR A ONE CYLINDER ENGINE

If, now, the current from the battery was permitted to flow through the spark coil all of the time it would spark continuously. To make it spark only when it is needed to explode a fuel charge a *timer* must be connected in circuit with the battery and the primary coil.

In its simplest form the timer consists of a cam mounted on the camshaft; the cam presses against a spring which is fixed at one end and has a contact point on its free end. When the corner of the cam strikes the spring it presses it against the stationary contact and this closes the primary circuit.

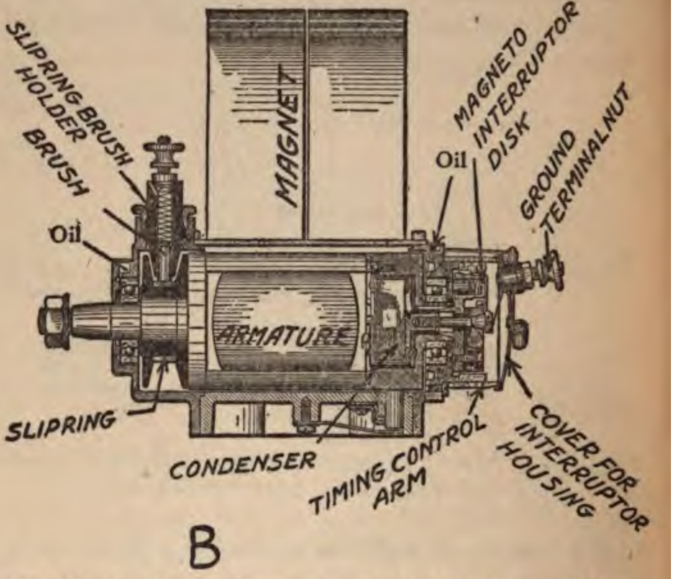


FIG. 30.—B. CROSS SECTION OF A BOSCH HIGH TENSION MAGNETO

The spark-plug, see B and C, is simply a metal tube with threads on the outside to permit it to be screwed into the head of the cylinder and inside of which a porcelain tube is fixed. A heavy wire is secured inside of the porcelain tube, one end terminating in a binding post and the other end projecting out $\frac{1}{8}$ of an inch. To the lower part of the metal plug another heavy wire is soldered and the ends of these two wires form a spark-gap about $\frac{1}{16}$ of an inch long, and they are connected to the ends of the secondary coil, as shown at A.

It is not necessary to use a wire to make a connection between the metal parts of the spark-plug

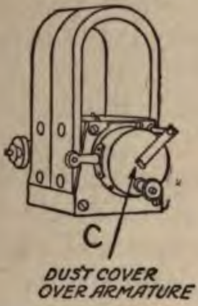


FIG. 30.—C. A BOSCH HIGH TENSION MAGNETO COMPLETE

and the secondary coil. Instead, what is called a *ground* is used, that is, the metal part of the spark-plug makes connection with the iron of the engine, and hence all you need to do to complete the circuit is to fix the other end of the secondary coil to any part of the engine where it is convenient to do so.

The High Tension Rotating Magneto.—To set up currents whose tension is high enough to make a jump spark with a magneto the armature must have two coils of wire wound on it just like the battery spark coil above described.

In this kind of a magneto when the armature rotates the *primary coil* on it sets up low tension currents so that no battery is needed, and these currents *induce* high tension currents in the secondary coil which is wound around it. Different from a spark coil, though, one end of the primary coil is connected to the iron core of the armature, that is, it is *grounded,* and the other end of the secondary coil is connected to a brush which presses on a slip-ring; in this way only one ring and one brush are needed, as shown at A and B in *Fig. 30.* A cross-section of a high tension magneto is shown at B and the magneto complete at C.

Where a stationary engine has two or more cylinders it is the usual practice to provide each one with a complete ignition system so that in this way they work independently of each other.

Governors and How They Work.—Two types of governors are used for keeping the speed of the engine steady, and these are (1) the *hit and miss governor* and (2) the *throttling governor.*

The Hit and Miss Governor.—It is so called because it allows the cam to open the gas inlet valve when the engine tends to slow down and keeps the valve closed when the engine begins to run too fast. If the load is at all variable the engine will very often miss firing its fuel charge and then perhaps fire it several times in succession.

How the Governor is Made.—There are many different forms of this type of governor, but a good and simple one is that used on the Otto engine, and this will serve to show the principle on which the others work.

It consists of (1) a pair of *flyballs;* (2) a *conical weight* to hold (3) the *governor shaft* down; (4) a *beveled gear* on the lower end of the shaft to rotate the flyballs, and this gear meshes with (4) another *beveled gear* on the camshaft. On the shaft is (5) a *sleeve* with a groove cut in it, and in this sets (6) the forked end of a *horizontal lever,* to which is fixed (7) a *vertical lever* with a fork on its free end.

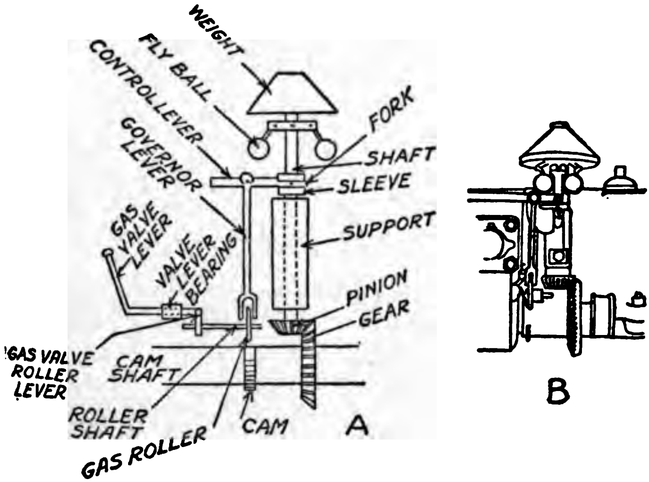


FIG. 31. FLYBALL HIT AND MISS GOVERNOR
A, A Diagram of the Governor. B, Otto Governor.

This latter forked lever straddles (8) a thin steel wheel called a *gas roller,* which is mounted on a *roller shaft.* Under the gas roller and on the camshaft there is (8) a *cam;* the roller shaft, which is hollow, slips over (9) the pin of a crank, or *roller lever,* as it is called, and finally this is fixed to (10) the *gas valve lever,* the arm of which rests on the end of the gas valve poppet, all of which are shown at A and B, in *Fig. 31.*

The Way It Works.—When the engine is running the balls are rotated by the vertical shaft by means of the beveled gears and the weight tends to hold the shaft down against the centrifugal force which makes them fly apart.

When the balls spread apart they lift up the grooved sleeve and, as the fork of the horizontal lever rests in the groove, it moves up with it; in turn this moves the vertical forked lever, which is fastened to it sidewise. When this action takes place the fork slides the roller over and makes it miss the cam on the camshaft.

The result is that the gas valve lever remains closed and hence the gas valve *misses,* that is, it does not take in any gas on the suction stroke.

But as long as the speed is right the balls do not fly apart wide enough to throw over the lever and the roller, the cam strikes it and the gas valve lever opens the gas valve.

The Throttling Governor.—This governor also has a pair of flyballs which are rotated in the same way as in the governor described above. The vertical shaft with the grooved sleeve works a lever that opens and closes a gas valve, or *throttle,* as it is called, in the gas supply pipe more or less in order to keep the speed uniform. It is shown in *Fig. 13.*

How the Engine is Oiled.—The chief parts of the engine to be oiled are (1) the piston, (2) the crankshaft bearings, and (3) the connecting rod bearings. Besides, there are numerous other smaller moving parts which must be lubricated.

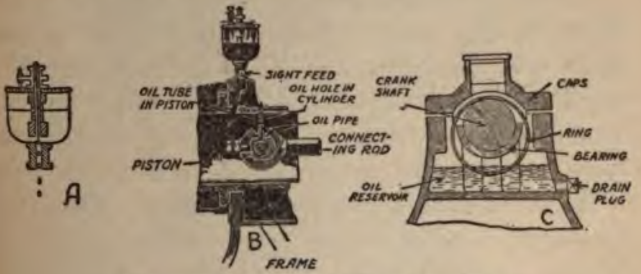


FIG. 32. HOW THE ENGINE IS OILED

A, Cross Section of a Sight Feed Oil Cup. B, Wipe Oiler for Connecting Rod Bearing on Piston. C, A Ring Oiler for Crankshaft Bearing.

The piston and the wrist pin are lubricated by a *sight feed oil cup,* that is, an oil cup which feeds down the oil drop by drop and which has a glass window in it so that you can see the rate at which the oil flows. An oil cup of this kind has either a regulating screw, or a handle, on top, so that the oil can be fed as fast or as slow as it is needed, or shut off entirely. It is shown at A and B in *Fig. 32,* and its position on the cylinder is shown at *B.* The piston has a groove cut in its periphery and as this passes the oil duct it fills with oil, and so lubricates the piston and the cylinder.

The bearing of the connecting rod on the wrist pin is lubricated by an oil tube from the same oil cup, which sets in the piston over and directly in a line with an oil *pipe* in the bearing, and this is also shown at B.

The bearings of the crankshaft are lubricated either by (1) *sight feed oil cups* or (2) by *ring oilers.* A ring oiler has an oil well, or reservoir, which is filled with oil and a metal ring which is large enough so that when it is hung on the shaft the lower edge dips into the oil, as shown at C.

As the shaft revolves the ring turns a little at a time with it and carries oil to the bearing as it moves round. With this system of oiling there is never any danger of hot boxes.

The bearings of the connecting rod on the crankshaft are oiled by a *wiper oiler.* A *sight feed oil cup* is mounted on an upright rod, or on the *crank-guard,* that is, a heavy metal sheet arched over the crank. The wiper consists of an oil tube set in the crank-pin bearing and having in it a piece of lampwick.

As the crank revolves, the lampwick strikes the open end of the oil cup pipe and wipes off the oil. When the wick is soaked with oil it reaches the bearing and the crankpin and keeps them lubricated.

The numerous other small parts to be lubricated are oiled by small oil cups or by hand through oil holes.

Kinds of Water Circulating Systems.—There are two simple ways to keep water circulating around

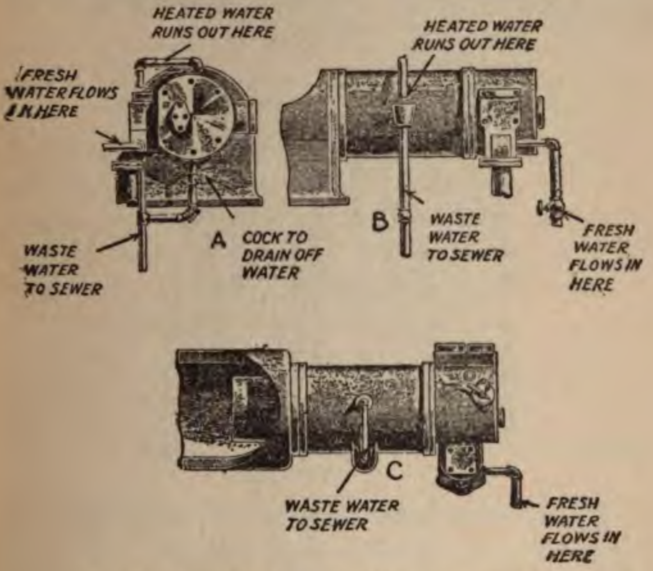

HEATED WATER RUNS OUT HERE
FRESH WATER FLOWS IN HERE
WASTE WATER TO SEWER
A
COCK TO DRAIN OFF WATER
HEATED WATER RUNS OUT HERE
B
WASTE WATER TO SEWER
FRESH WATER FLOWS IN HERE
C
WASTE WATER TO SEWER
FRESH WATER FLOWS IN HERE

FIG. 33. COOLING BY A STEADY FLOW OF WATER

A, End View of the Engine. B, Side View of the Engine. C, Top View of the Engine.

the cylinder to keep it cool, and these are (1) by using a stream of city water, or water that is under pressure from any other source, and (2) by employing a water tank.

Using a Steady Flow of Water.—Where a steady flow of water can be had it is simply piped into the cylinder jacket through a cock at its lower end; the heated water is then carried off by a spout near the top of the jacket, as shown at A, B and C in *Fig. 33,* when it empties into a funnel and is carried away by the waste pipe to a sewer.

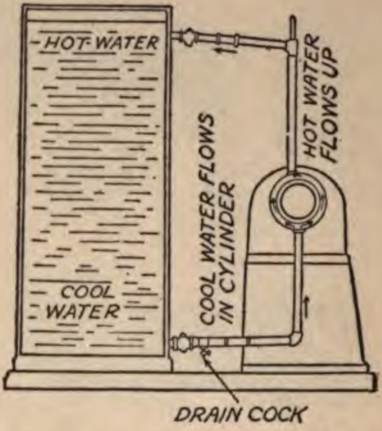


FIG. 34. TANK OR THERMO-SIPHON COOLING SYSTEM

The Cooling Tank, or Thermo-Siphon System.—Where flowing water is not available engines of from 1 to 15 horsepower can be cooled by means of a tank, as shown in *Fig. 34.*

When the water in the cylinder jacket heats up it gets lighter and rises through the pipe into the tank, while the cold water, since it is the heaviest, falls to the bottom of the tank and then flows on back into the cylinder jacket. In this way the water is circulated, or siphoned, by its *thermal action,* that is the action of the heat itself.

The Exhaust Pot and Exhaust Pipe.—When the burnt gases in the cylinder are exhausted directly into the air they sound like the staccato reports of a Lewis machine gun mowing down a detachment of *boches.*

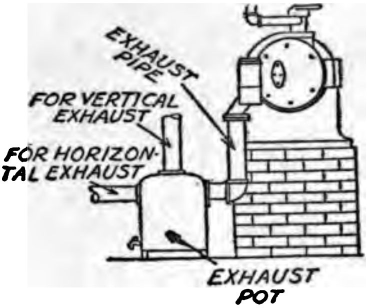


FIG. 35. THE EXHAUST POT OF A GAS ENGINE

To silence these noises an *exhaust pot* is used, and this is simply a large iron, or other vessel, as shown in *Fig. 35,* into which the burnt gases are driven by the exhaust stroke; they then expand in it until the pressure they exert is just about that of the atmosphere, when they exhaust into the open air without noise.

CHAPTER IV

STATIONARY AND PORTABLE GASOLINE ENGINES

It is clear that if you want to develop power with an internal combustion engine and natural or artificial gas is not available, or if you want an engine of this type that you can move about, or that will move you about, you must have one that will burn some kind of liquid fuel.

Now gasoline for any one of a number of excellent reasons is the ideal liquid fuel and hence, it is largely used for running *stationary* and *portable* engines up to 30 horsepower.

Stationary and Portable Engines Defined.—A *stationary engine* is, as everybody knows, one whose position after it is once set remains so, that is, it is intended to stay and run in a fixed place.

A *portable engine* is simply an engine of the stationary type which is mounted on skids or on a hand or horse-drawn truck, as shown in *Fig. 36,* so that it can be hauled about by some other power than its own and used wherever it may be needed.

Difference Between a Gas and a Gasoline Engine.—The chief mechanical difference between a gas and a gasoline engine of the stationary type is that in the former gas is admitted directly into the cylinder of the engine without the use of any intervening or accessory apparatus, while in the latter means must be provided for (1) *storing the gasoline;* (2) *bringing it to the cylinder,* and (3) *breaking it up into a spray* so that it will mix with air to form the fuel mixture.

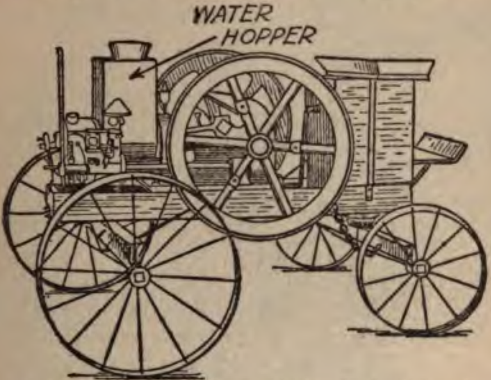


FIG. 36. A PORTABLE GASOLINE ENGINE

Further, a gasoline engine is exactly like a gas engine in that it has the same kind of inlet and exhaust valves, governor, ignition and oiling systems.

A hot-tube, or *hot ball* igniter must not be used on a gasoline engine, but any one of the electric igniters of the kinds described in Chapter II is well adapted to fire a gasoline fuel charge. In stationary gasoline engines the cylinder cooling systems used are identical with those employed with gas engines.

But for portable engines, a *hopper,* or iron box, is usually secured to the top of the engine and this holds the supply of water which is circulated by the *thermo-syphon system* as explained in the preceding chapter under the heading of *Cooling Tanks.*

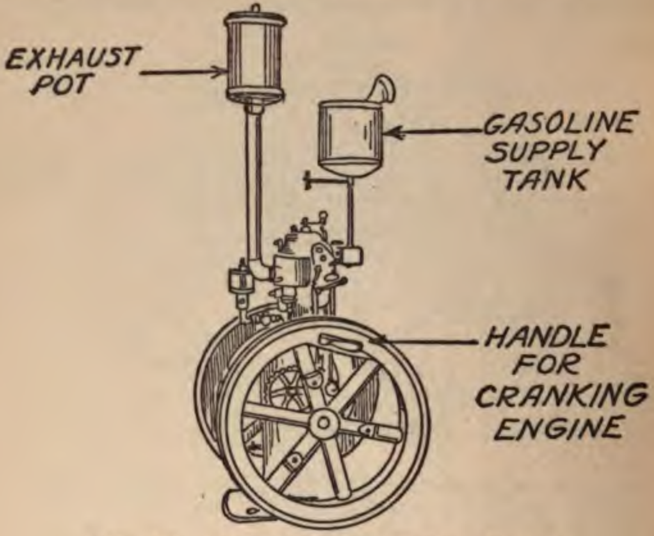


FIG. 37. A GRAVITY GASOLINE FEED SYSTEM

How the Gasoline System Works.—*The Gasoline Supply Tank.*—The tank that holds the supply of gasoline can be set either (1) *above* the engine when it is fed into the cylinder through the gasoline valve by gravity, or (2) *below* the level of the engine when it is pumped to the *gasoline valve* and is then drawn into the cylinder.

The Gravity Feed System.—For small engines the gasoline tank can be placed above the engine as shown in *Fig. 37*.

The Pump Feed System.—For larger engines the gasoline tank must be buried in the ground or placed in a brick-lined vault outside of the building containing the engine.

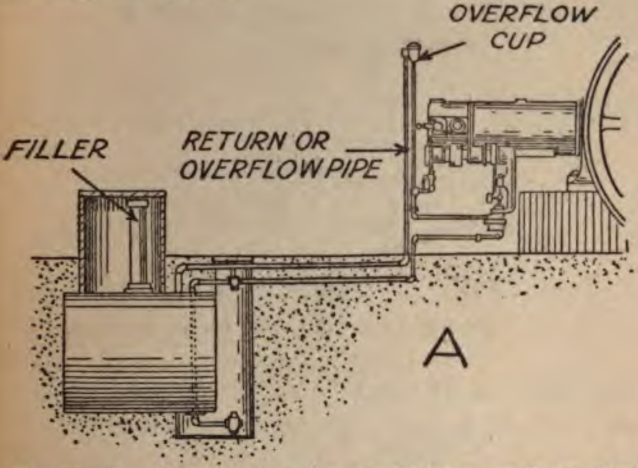


FIG. 38—A. UNDERGROUND SUPPLY TANK WITH PUMP FEED SYSTEM

To make the gasoline supply perfectly safe the tank must be below the level of the *gasoline pump* a foot or so, and it should be at least 30 feet away from the engine. The filler should project above the ground, and the *gasoline cock* in the pipe line which leads to the pump must be easily get-at-able. It is shown at *A* in *Fig. 38*.

The gasoline pump is of the ordinary *plunger* kind, like those used for pumping water, and it is worked by an eccentric on the camshaft, as shown at *B.* The piston rod of the pump has a handle attached to it, so that enough gasoline to start the engine can be pumped by hand should it be needed.

The pump draws the gasoline from the bottom of the supply tank into an overflow cup, that is, a small vessel which holds about ½ a pint of gasoline and sets above the engine. The excess gasoline that is pumped into the overflow cup runs back to the tank through a return pipe. The gasoline flows by gravity from the inside of the overflow cup to the gasoline valve.

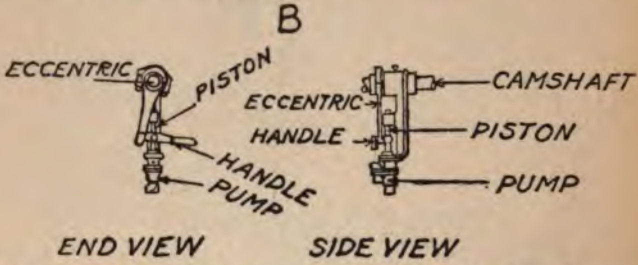


Fig. 38—B. Plunger Pump for the Pump Feed System

The Gasoline Valve.—Numberless schemes have been devised to break up the gasoline into a spray and mix it with the right amount of air to make the fuel mixture.

For a stationary gasoline engine a very simple and satisfactory device for this purpose is to use a *needle* *valve* and set it into the casing of the fuel inlet valve just back of the valve head, as shown in *Fig. 39.*

A needle valve is merely a small tube one end of which is formed into a nozzle with a little hole in it. A small rod, or *needle,* with a tapering point, sets in the tube and can be adjusted so that the amount of gasoline flowing through the nozzle can be varied. The end of the needle valve tube that projects outside of the cylinder is connected to the overflow cup by a length of pipe.

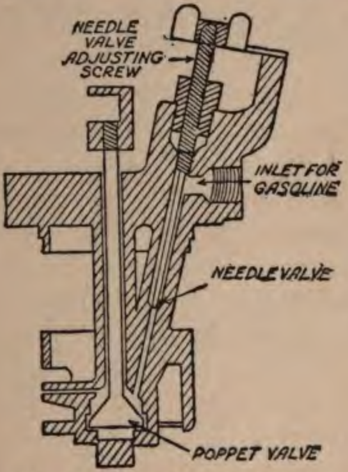


Fig. 39. The Gasoline Valve

The way the gasoline valve works is like this: when the fuel inlet valve opens the suction stroke draws the gasoline from the overflow cup through the gasoline valve into the cylinder in a spray. The minute particles are vaporized by the heat when they readily mix with the air which is taken in by the air valve at the same time.

As the fuel inlet valve is controlled by the governor in the same way as the gas inlet valve on a gas engine, just enough gasoline is taken into the cylinder to drive the engine under all conditions of load, be it light or heavy.

CHAPTER V

MOBILE GASOLINE ENGINES

Mobile gasoline engines are those made small, light and strong enough so that they can be used to power motorcycles, motor cars, motor boats and airplanes and drive these various vehicles over land, water or through the air. While these mobile engines work on the same general principle as stationary gasoline engines, yet they differ greatly in detail and each type must be designed for the special work it has to do.

PART I

THE MOTORCYCLE GASOLINE ENGINE

All motorcycle engines are built on the four stroke cycle principle, and they are made with one, two, four and eight cylinders.[1] The one and four cylinder engines are of the vertical type and the two and the eight cylinder engines are of the V type, as shown in *Fig. 40.*

The Fuel Supply System.—The gasoline system or *fuel system,* as it is called, consists of two chief parts, and these are (1) the *tank,* which contains the supply of gasoline, and (2) the *carburetor,* which regulates the amount of gasoline used, breaks it up into a spray as it is needed and mixes it with air to make the fuel mixture.

The Gasoline Supply Tank.—In motorcycles the tank is always set above the engine and the gasoline is fed into the carburetor by gravity.

Why a Carburetor is Used.—Instead of the simple gasoline valve which is used on stationary engines, all mobile gasoline engines employ a more complicated but better device for the purpose, called a *carburetor.*

---

[1] The eight cylinder motorcycle was a racing machine built by the Curtiss Co., of Buffalo, N. Y.

The reason a gasoline valve cannot be used is that it delivers the same amount of fuel to the cylinder each and every stroke unless it is regulated by a governor, while with a carburetor the amount of gasoline needed for varying loads can be regulated to a nicety without a governor, which, indeed, could not be used because the speed of the engine must be

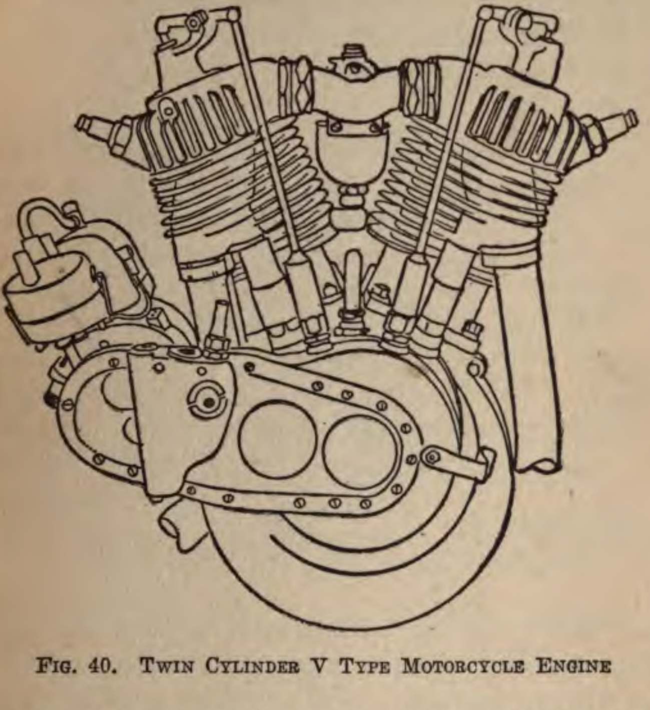


FIG. 40. TWIN CYLINDER V TYPE MOTORCYCLE ENGINE

variable at all times and under the control of the operator.

How a Simple Carburetor Works.—*A* in *Fig. 41* shows a diagram of a carburetor in its simplest form, so that you can understand it. It is made up of (1) a *float chamber;* (2) a *float valve;* (3) a *nozzle;* (4) an *air inlet pipe,* and (5) a *mixing chamber.*

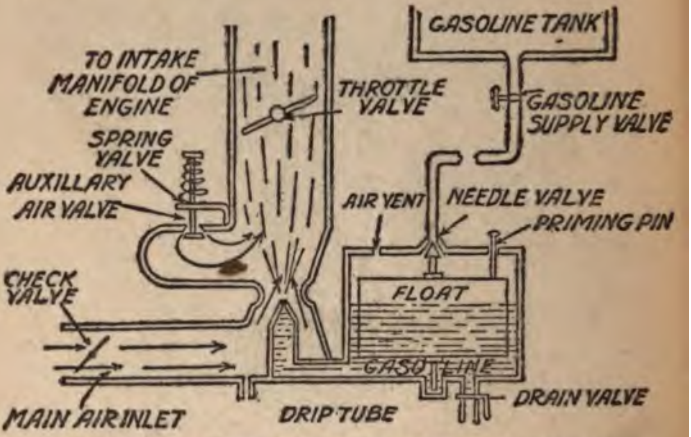


FIG. 41—A. CROSS SECTION OF A SIMPLE CARBURETOR

The float chamber is connected to the supply pipe which leads to the tank of gasoline. It has a needle valve in it and this is fixed to the hollow metal float; when the float is down the gasoline from the tank flows into the float chamber and as it fills the float rises until the needle valve cuts off the supply.

There is an air vent in the float chamber so that it will not get air-bound and thus prevent the gasoline from running into or out of it. It also has a *priming pin,* with which you can press the float down and fill the float chamber full of gasoline, or *flood it,* as it is called, when you want to start the engine.

The float chamber is connected to the nozzle with a pipe and when the gasoline is drawn through the nozzle by the suction stroke of the engine it forms a spray as shown at *A*. But to break up the gasoline into minute particles and make an explosive mixture of it, air must be drawn up and mixed with it at the same time.

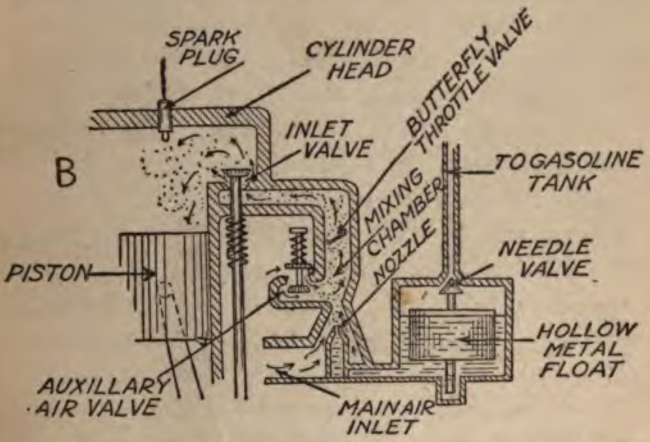


FIG. 41—B. HOW THE CARBURETOR AND INLET VALVE OF THE ENGINE ARE CONNECTED

To give the gasoline the required amount of air a large air-pipe, which is open at one end, encloses the spray-jet at the other end. This pipe is bent and is *constricted,* that is, it is made smaller just above the jet and this gives the air a higher pressure when it is drawn through the pipe because it also forms a kind of a nozzle.

At a point just above the constriction the tube is enlarged to form a space for the air and gasoline to mix in and hence this part of the carburetor is called a *mixing chamber.* An inlet pipe connects the mixing chamber of the carburetor with the cylinder of the engine as shown at *B.* Where two or more cylinders are to be fed at the same time the pipe branches out and it is then called a *manifold.*

How a Regular Carburetor is Made and Works.—While a real carburetor is made and works exactly like the simple one I have described, it is built much more compactly and it has one or more *auxiliary air valves* to regulate to a nicety the amount of air needed for high and low speeds. The construction of the automatic auxiliary air valve is also shown at *A* and *B.* It is simply a valve working against a compression spring; when more air is needed the suction of the piston opens it and when enough air has been drawn in the spring closes it.

The main, or *primary air inlet* of the carburetor has a *butterfly valve* in it, so that the air can be shut off to make it easy to start the engine and to make a *rich* or a *lean* fuel mixture, as desired. Finally, a *throttle valve* is set in the top of the mixing chamber so that the amount of fuel mixture which goes to the cylinders can be regulated and the speed of the engine controlled. A *throttle rod* runs to the handle-bar of the motorcycle so that the rider can work the throttle.

A cross-section of a Stromberg carburetor is shown at *A* in *Fig. 42,* and it is fitted with many little refinements such as a needle valve adjusting screw, a gasoline strainer, drain cock, hot-air horn, etc. A view of the carburetor complete is shown at *B.*

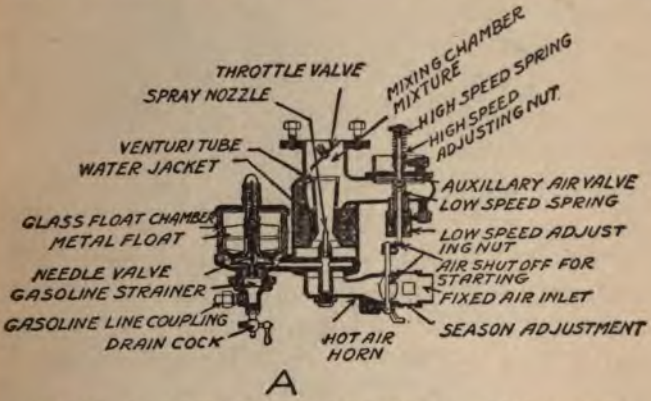


FIG. 42—A. CROSS SECTION OF A STROMBERG CARBURETOR

The Electric Ignition System.—The only type of ignition system used on motorcycle gasoline engines is the *jump-spark.*

As in stationary gasoline engines there are two kinds of jump-spark systems used on motorcycle engines, and these are (1) the *jump-sparkcoil* system, and (2) the *high tension magneto* system.

On the cheaper makes of motorcycles the jum spark coil system is used, while the better makes ar equipped with the high-tension magneto-system. Th jump-spark-coil system and the high-tension syste used on motorcycle and other mobile engines wor on the same principle as those described in connection with gas engines.

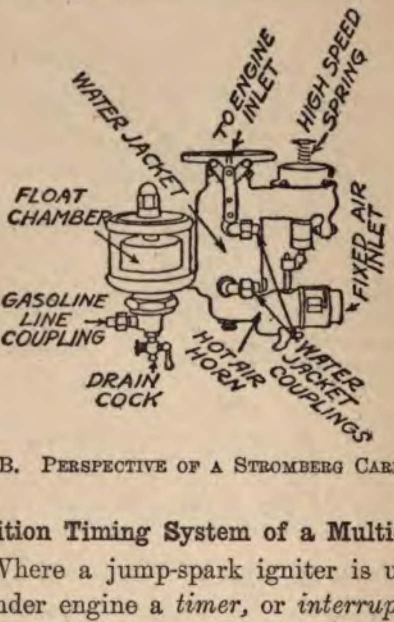


FIG. 42—B. PERSPECTIVE OF A STROMBERG CARBURETOR

The Ignition Timing System of a Multi-Cylinder Engine.—Where a jump-spark igniter is used on a single cylinder engine a *timer,* or *interruptor,* as it is called, is used to *make* and *break* the primary circuit, as previously explained, but where two or more cylinders must be fired successively a revolving timer, or *distributor,* as it has been named, is employed.

A distributor consists of a disk around which are fixed as many metal contact segments as there are cylinders to be fired, and each segment is connected by a wire with a spark-plug, as shown at *A* in *Fig. 43.*

A metal contact arm is pivoted to the center of the disk and the former makes contact with some part of the engine, that is, it is *grounded,* so that it will form a connection with the spark-plugs.

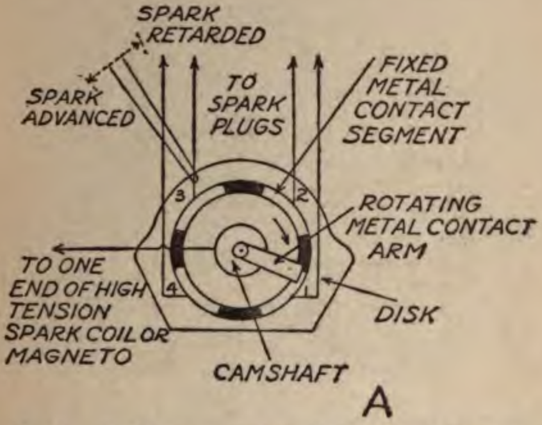

SPARK RETARDED
SPARK ADVANCED
TO SPARK PLUGS
FIXED METAL CONTACT SEGMENT
3
2
ROTATING METAL CONTACT ARM
TO ONE END OF HIGH TENSION SPARK COIL OR MAGNETO
4
DISK
CAMSHAFT
A

FIG. 43—A. A DISTRIBUTOR FOR TIMING THE IGNITION OF A FOUR CYLINDER ENGINE

The contact arm is turned by the camshaft and makes one complete revolution to every two revolutions of the crankshaft. Now every time the arm makes contact with one of the segments of the disk a spark takes place between the electrodes of the spark-plug that is connected with that particular segment all of which is clearly shown at *B*.

A lever is attached to the disk of the distributor and goes up to a control lever on the handle-bar, so that the disk can be moved ahead or set back, when the spark will be advanced or retarded, as the case may be.[1]

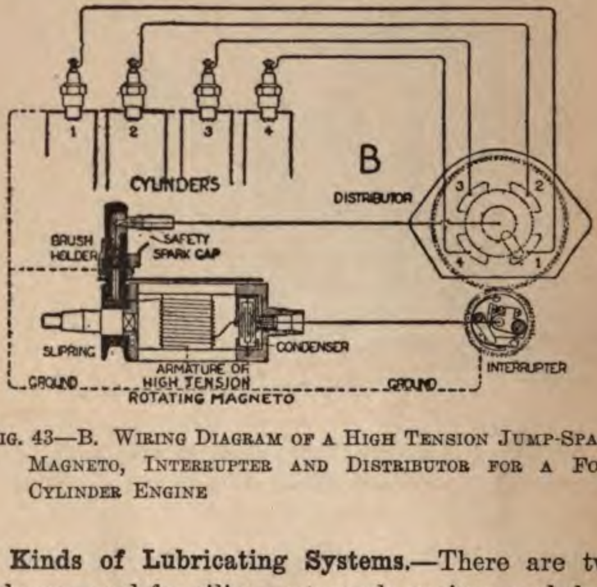


FIG. 43—B. WIRING DIAGRAM OF A HIGH TENSION JUMP-SPARK MAGNETO, INTERRUPTER AND DISTRIBUTOR FOR A FOUR CYLINDER ENGINE

Kinds of Lubricating Systems.—There are two schemes used for oiling motorcycle engines, and these are (1) the *splash system* and (2) the *force feed system.*

---

[1] The theory of advancing and retarding the spark is explained in *Keeping up with Your Motor Car* by the present author and published by D. Appleton & Co., New York.

The Splash System.—This is a simple system for oiling the working parts of a mobile internal combustion engine but it must be looked after rather closely. In this system the oil is (1) poured into the crank-case through an opening called a *breather;* (2) it is fed into it from a tank by gravity, or (3) it is forced into it from a tank by a pump.

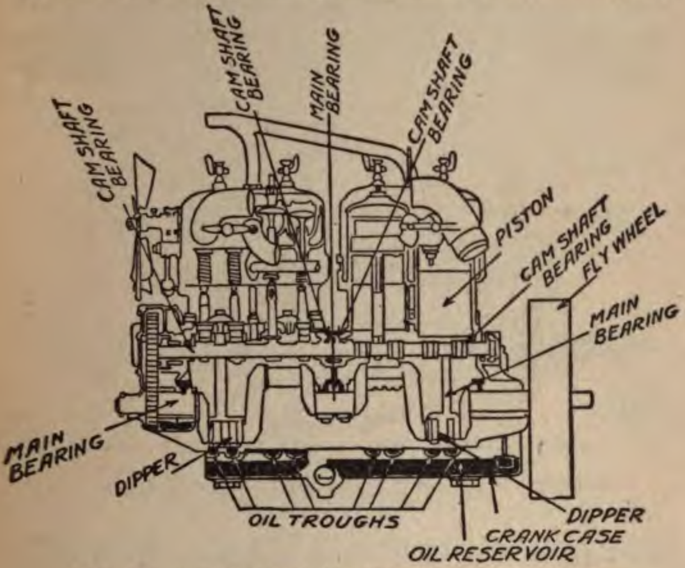


Fig. 44. The Splash Lubricating System of a Four Cylinder Engine

The oil is then splashed into the cylinder and onto the connecting rod bearings by little *scoops,* or spoons, fixed to the lower ends of the connecting rods which dip into the oil. It is shown in *Fig. 44.*

The Force Feed System.—All the finer makes of mobile engines for all purposes use the force feed system of lubrication, or *mechanical oilers* as they are sometimes called.

In this system the oil is put into a well in the bottom of the crankcase, or *sump* as it is called, and from there it is forced by a pump worked by the engine through an oil tube above and parallel with the crankshaft.

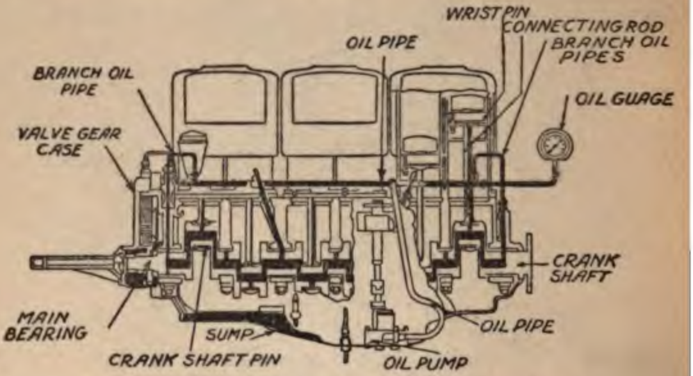


FIG. 45. THE FORCE FEED LUBRICATING SYSTEM

From this tube the oil is forced or flows through ducts, or holes, in the crank-webs to the crankshaft bearings, on through to the crank-pins and through hollow connecting rods to the wrist-pins. The pistons are kept lubricated by the oil that runs out and which is thrown from the lower ends of the connecting rods. The whole scheme is shown in *Fig. 45.*

Cylinder Cooling Schemes.—There are two kinds of cooling systems for keeping down the heat of motorcycle engines, and these are (1) the *air cooling system* and (2) the *water circulating system;* then there is (3) a combination of these two systems.

In air-cooled engines the cylinders are either cast with thin parallel rings around them or else have copper rings fixed to the outside walls as shown in *Fig. 46.* When the engine is running the rings get hot and the heat is radiated by them into the air.

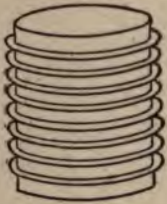


FIG. 46. A RING AIR COOLED CYLINDER

As the water circulating and combined air and water cooling systems are seldom found on motorcycle engines but are used on every make of motor car engine, with one or two exceptions, these systems will be described under the next section which treats of motor car engines.

How the Muffler is Made and Works.—The *muffler*[1] of a motorcycle engine must be small and light. To provide such a muffler six or more *baffle plates* with holes drilled through them on opposite sides are bolted together and to a head, as shown in *Fig. 47*, and the exhaust pipe is screwed into the latter.

---

[1] The muffler is a silencer and is used in mobile engines instead of the exhaust pot.

Now when the exhaust gases are discharged from the exhaust pipe or manifold, the gases pass through the holes in the first baffle plate, then the next, and so on until they reach the outside air. This arrangement of plates makes the streams of gases change their direction and breaks them up half-a-dozen times before they reach the outside air, and by this time the force of them is quite effectively dissipated.

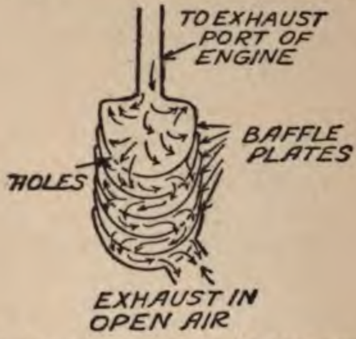


Fig. 47. A Muffler for a Motorcycle

PART II

THE MOTOR CAR GASOLINE ENGINE

The four cycle engine is the only type used for motor car engines, and all of them have from four to twelve cylinders, or *twin sixes* as the latter are called, and these are of the V type.

About the Fuel Feed System.—*Kinds of Feed Systems.*—There are three kinds of fuel feed systems used on motor car engines, and these are (1) the *gravity feed,* (2) the *air pressure feed,* and (3) the *vacuum feed* system.

The Gravity Feed System.—As in stationary and motorcycle engines a gravity feed is sometimes used, in which case the tank is placed under the front seat of the car, when it is, of course, higher than the carburetor.

The Air Pressure Feed System.—In this system the gasoline tank is placed back of the rear axle and it is lower than the carburetor. Air is pumped into the tank either by a hand pump or by a pump driven by the engine, until it is under three or four pounds pressure, when the compressed air forces the gasoline into the carburetor. The scheme is shown in *Fig. 48.*

The Vacuum Feed System.—The supply tank in this system is likewise placed back of the rear axle and below the level of the carburetor.

The gasoline is drawn from the supply tank into a small *fuel tank,* which sets above the carburetor, by the vacuum produced by the suction of the pistons in the cylinders. The fuel tank has a float with a valve on it which cuts off the gasoline from the supply tank when the former is partly filled.

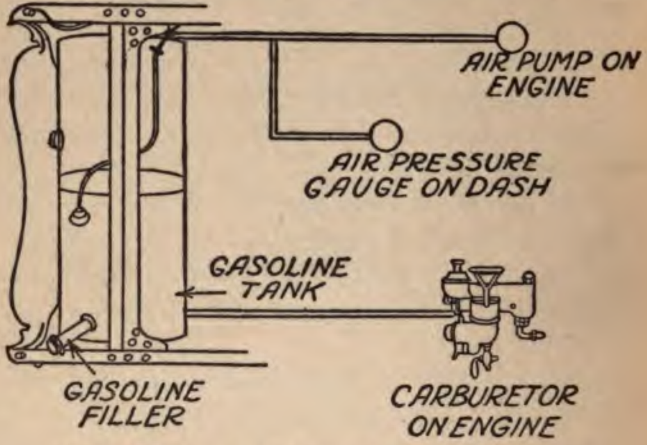


FIG. 48. THE AIR PRESSURE FUEL FEED SYSTEM

The fuel tank is connected to the carburetor and the gasoline flows into the latter by gravity. This system is shown in *Fig. 49.*

The Use of the Carburetor.—The carburetor is identical with the one described in the beginning of this chapter. The amount of fuel mixture admitted into the cylinders is controlled by a *hand throttle* and a *foot accelerator,* both of which are connected with and operate the throttle valve in the carburetor.

The Ignition System.—The jump-spark system is the only type used on motor car engines; but there are three kinds of jump-spark apparatus and these are (1) the *battery and spark coil system,* (2) the *high tension magneto,* and (3) the *circuit breaker spark coil system.*

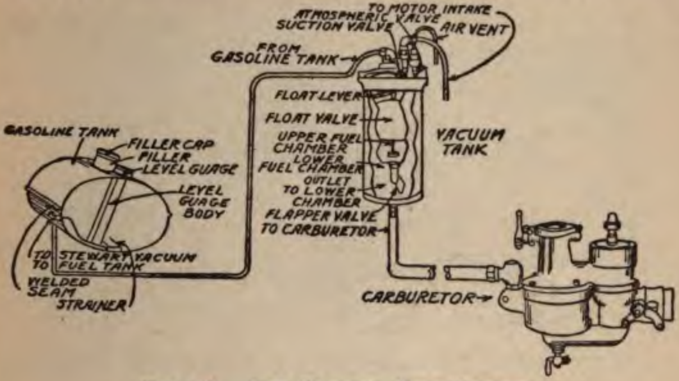


FIG. 49. THE VACUUM FEED SYSTEM

The battery and spark-coil system, which is the same as that used in stationary and motorcycle engines, has all but been displaced by the magneto and the newer circuit breaker spark coil systems. Many motor car engines are equipped with this system alone while some of the better engines have both it and the high tension magneto, the last named also having been explained in Chapter III.

In the Circuit Breaker Spark-Coil ignition system a spark coil made exactly like the battery spark coil is used, but it has no *vibrator* on it.

The circuit breaker is formed of a cam which has as many corners on it as there are cylinders to be fired. This cam is fixed to a shaft which is geared to the camshaft of the engine and this takes the place of the vibrator, in fact it acts exactly like the interruptor on a magneto.

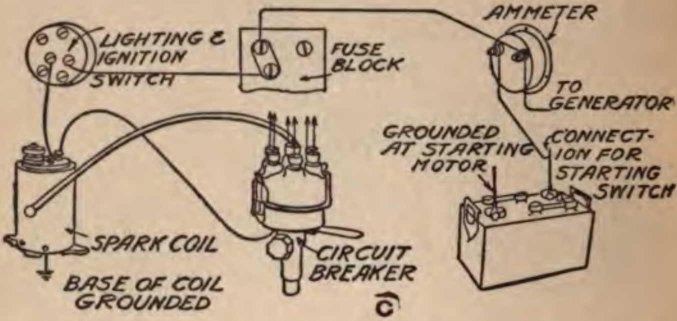

AMMETER
LIGHTING & IGNITION SWITCH
FUSE BLOCK
TO GENERATOR
GROUNDED AT STARTING MOTOR
CONNECTION FOR STARTING SWITCH
SPARK COIL
CIRCUIT BREAKER
BASE OF COIL GROUNDED

FIG. 50. WIRING DIAGRAM OF A SIX CYLINDER CIRCUIT BREAKER SPARK COIL IGNITION SYSTEM

The *distributor* is the timing device and it is made like the one described in connection with the magneto. The contact arm is rotated by the same shaft that carries the cam of the circuit breaker. The spark-coil is energized by a storage battery, which also delivers current for the electric starter and the electric lighting system. *Fig. 50* is a diagram of the system.

Engine Cooling Systems.—Since only a small amount of water can be carried to cool the engine it must itself be cooled by some means, and this is done by a *radiator.*

A radiator is built in one of two different ways, namely, (1) with small vertical pipes *through* which the heated water flows and which are cooled by the air blowing *on* them, or (2) with horizontal pipes *around* which the heated water flows and which are cooled by the air blowing *through* them. The first kind is called a *tubular radiator* and the second is called a *cellular radiator,* and these are shown at *A* and *B* in *Fig. 51.*

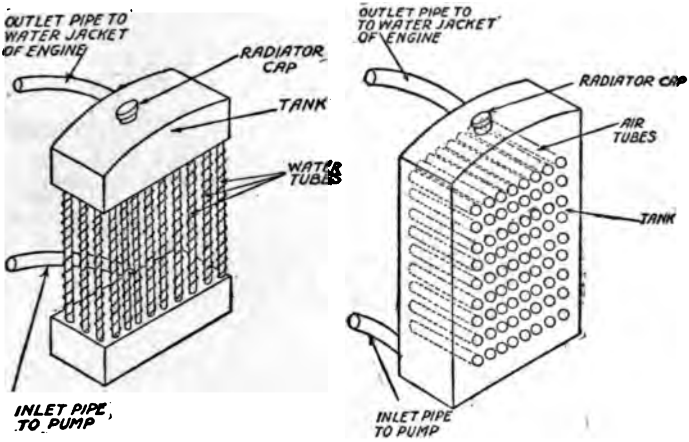


FIG. 51—A AND B. RADIATORS FOR MOTOR CARS

There are two ways in which the water in the radiators and the jacketed cylinders is kept circulating, and these are by (1) the *thermo-siphon system* and (2) the *pump circulating system.* In the former the water is kept circulating by the heat itself in exactly the same way as in the cooling tank system described in Chapter III. In the latter it is forced through the radiator and the jacketed cylinder by a rotary pump.

About Lubricating Systems.—Both the *splash and force feed* lubricating systems which are used for oiling motorcycle engines are likewise employed for oiling motor car engines.

Besides the two above distinct types there are three other kinds of systems derived from them, and these are (1) the *splash circulating,* (2) the *splash and force feed* and (3) the *full force feed.*

In the splash circulating system the oil is put into the sump, or reservoir of the crankcase. Troughs are cut in the floor of the crankcase and the flywheel which runs in the oil sump keeps the troughs full of oil; the connecting rods dip into them and splash the oil into the cylinders as before; the oil is also carried up and into the oil tube which oils the bearings.

Where the *splash force feed system* is used the oil is forced by a pump through an oil tube into the crankshaft bearings and from these the oil drops back into the splash troughs in the crankcase and the connecting rod splashes it to all parts of the engine.

The *full force feed system* is the only one where the splash is not used. The oil is pumped from the sump through an oil tube to the bearings and then it runs through ducts in the crank-webs to the crank-pins and, finally, through hollow connecting rods.[1]

The Construction of the Muffler.—A motor car muffler is made on the same principle as that of a motorcycle muffler but as room on a motor car is not at a premium it is made considerably larger.

A simple muffler consists of two or more pipes fixed one in the other; each pipe is closed at one end and holes are drilled through near the end that is closed, as shown in *Fig. 52.*

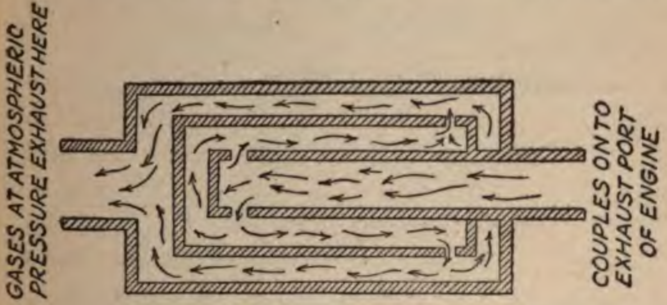

GASES AT ATMOSPHERIC PRESSURE EXHAUST HERE
COUPLES ON TO EXHAUST PORT OF ENGINE

FIG. 52. A MUFFLER FOR A MOTOR CAR

When the waste gases exhaust from the cylinders into the inside pipe they shoot to the end of it and then pass out of the holes into the second pipe; they next flow out of oppositely disposed holes, which change their direction, and finally they escape silently into the open air.

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[1] All of these systems are explained and pictured in detail in my book *Keeping Up with Your Motor Car,* published by D. Appleton & Co., New York.

Hand and Electric Starters.—Motor car engines are started either (1) by *hand* or (2) by an *electric motor.*

Hand Starters.—A few small new cars and a lot of the old-timers have engines with ratchet handles to crank them, and these are thrown out of gear the instant the engines start.

The Electric Starter.—Every up-to-date engine is equipped with an electric starter, and this is formed of four pieces of apparatus, namely, (1) a *storage battery,* (2) an *electric motor,* (3) a *motor drive,* and (4) a *starting switch,* and these are connected up, as shown at *A* in *Fig. 53.*

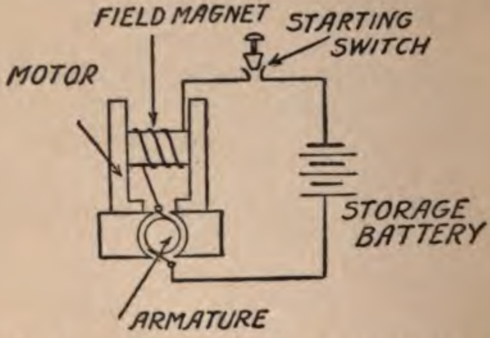

FIG. 53—A. WIRING DIAGRAM FOR AN ELECTRIC STARTER

The storage battery is formed of prepared lead plates, or *girds,* immersed in a weak solution of sulphuric acid, as shown at *B.* Three, six, or twelve cells of storage battery are generally used, and these

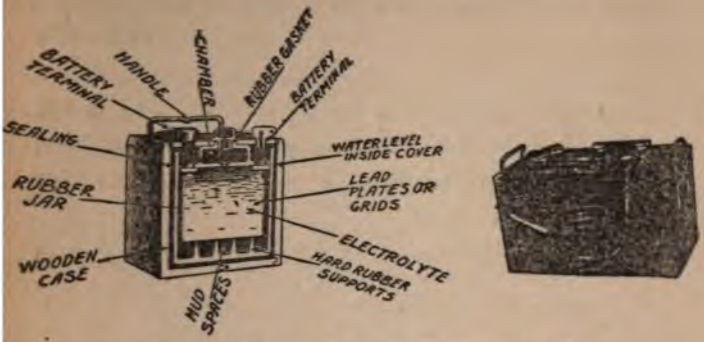

FIG. 53—B. HOW A STORAGE BATTERY IS MADE

must be charged with a current generated by a dynamo.

Now a dynamo and a motor are made exactly alike,

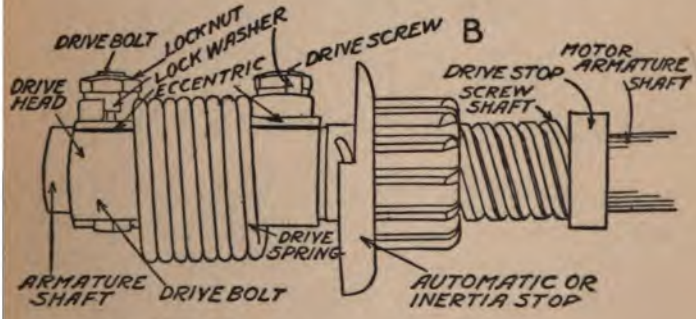

FIG. 53—C. THE ELECTRIC ENGINE DRIVE

and if you rotate the armature the machine will generate a current, and then it is called a *dynamo;* on the other hand if you pass a current through the machine it will rotate the *armature* and then it will be a *motor*.

The motor drive is the mechanical part of the starter; it is formed of a screw gear mounted on the projecting shaft of the electric motor; it meshes with teeth that are cut on the rim of the flywheel of the engine, as shown at *C*, and demeshes from it after the engine is started. It is shown complete at *D*.

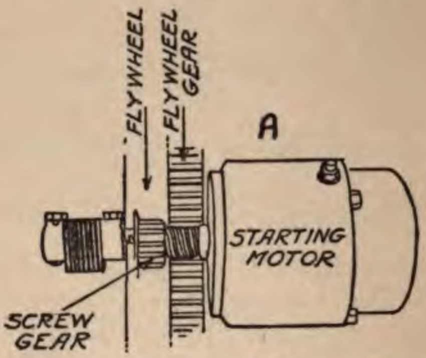

Fig. 53—D. The Electric Starter Complete

The switch is a simple device for opening and closing the circuit. Now when you throw on the switch the storage battery energizes the motor and this screws the drive gear into the flywheel and turns it; as soon as the engine has started, the motor drive demeshes automatically; you release the switch and the electric motor stops. When the engine is running the motor can then be driven by it, and it will then generate current and charge the storage battery.

The Knight Sleeve Engine.—To get rid of the noise that the poppet valves make, Knight invented an engine in which the inlet and exhaust ports are opened and closed by a sleeve that slides between the cylinder and the piston. It is shown in *Fig. 54.*

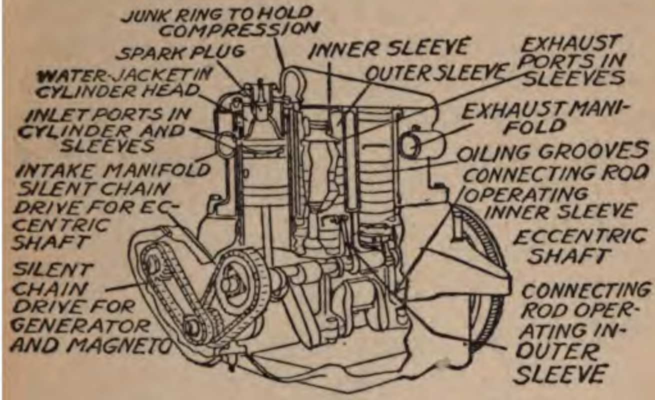
JUNK RING TO HOLD COMPRESSION
SPARK PLUG
INNER SLEEVE
EXHAUST PORTS IN SLEEVES
WATER-JACKET IN CYLINDER HEAD
OUTER SLEEVE
INLET PORTS IN CYLINDER AND SLEEVES
EXHAUST MANIFOLD
OILING GROOVES
INTAKE MANIFOLD
CONNECTING ROD OPERATING INNER SLEEVE
SILENT CHAIN DRIVE FOR ECCENTRIC SHAFT
ECCENTRIC SHAFT
SILENT CHAIN DRIVE FOR GENERATOR AND MAGNETO
CONNECTING ROD OPERATING IN OUTER SLEEVE

FIG. 54. THE KNIGHT SLEEVE VALVE ENGINE

PART III

THE MOTOR BOAT GASOLINE ENGINE

Gasoline engines for motor boats are of the two and four cycle types and are made with one, two, four, six and eight cylinders.

The Fuel Feed System Again.—The *gravity feed,* the *air pressure feed,* and the *vacuum feed* systems of fuel supply are all used on motor boat engines, and these are identical with those used on motor car engines.

In small boats, the gasoline tank is often made to fit in the bow of the boat, and as this is higher than the carburetor the gasoline flows down by gravity. Where a larger supply of fuel is wanted a cylindrical pressed steel tank can be mounted on the boat back of the seat just as it is on a runabout car.

The regular float valve carburetor is used on motor boat engines, and the speed of the engine is controlled by a *throttle,* that is, by a lever which opens and closes the throttle valve. On large engines the fly-ball type of governor is used, and by means of it any speed desired can be kept up.

Electric Ignition Systems.—There are three kinds of igniters used for firing the fuel charge of motor boat engines, and these are (1) the *make and break,* (2) the *jump-spark coil,* and (3) the *magneto system.*

The make and break scheme of ignition is used on single cylinder engines. Where a make and break coil is used the *timer* is worked by an *eccentric* on the camshaft. It is preferred to a high tension system, as it is not as easily short-circuited by water.

The jump-spark coil system is practically obsolete on motor boat engines, the more positive and less troublesome magneto having all but superseded it.

The Oiling Systems.—On small engines grease and oil cups are used to lubricate the piston and crankshaft. These cups have been described and pictured in Chapter III. The larger engines are oiled by the splash and force feed systems, as explained under the heading of *Motorcycle and Motor Car Gasoline Engines.*

The Engine Cooling System.—Since a constant supply of cold water is always at hand for cooling a motor boat engine a radiator is not needed. The water is pumped from that on which the boat rides, through an intake pipe that connects the supply with the jacketed cylinders, and it flows out of the latter back to the supply by an outlet pipe.

Kinds of Pumps Used.—There are three kinds of pumps used on motor boat engines, and these are (1) the ordinary piston, or *plunger pump;* (2) the *centrifugal pump,* and (3) the *gear pump.*

Where a plunger pump is used it is driven by an eccentric on the camshaft just as it is when used for pumping gasoline as shown in *Fig. 38.* Centrifugal and gear pumps are also used in water circulating systems.

The Exhaust Pipe and Muffler.—The exhaust pipe of the engine gets red-hot, nearly, and to keep it from burning the boat where it goes through it must be *jacketed,* that is, it must be enclosed in another pipe and be cooled by water circulating between them. The exhaust is made on the same principle as that of a motor car engine.

PART IV

AIRPLANE ENGINES

Engines for airplanes are of two types, and these are (1) the regular *stationary cylinder type* and (2) the *revolving, or gyro type.*

The first kind of engines are built like motor boat and motor car engines, only very much lighter for the power they develop. They are made with from four to twelve cylinders; they use carburetors, and have magneto ignition, radiators with water circulating pumps, and *force feed* oiling systems.

The Famous Liberty Motor.—The need of a light and powerful airplane engine that could be made in large quantities was felt as soon as the United States got into the war.

The work of designing this engine, or motor, as it was popularly called, was begun in the early part of 1915; by fall work was started on its construction, and in the spring of 1916 the first engine was completed. This engine was a *twin-six,* that is, it had 12 cylinders and was of the V type. After testing it a second time a more powerful engine was built on the same general lines. It had forged steel cylinders instead of iron ones with water jackets which were of pressed steel, and these were welded together by the oxy-acetylene process.

After more tests with this engine a third one was built in the spring of 1917; this one was much lighter in weight and all parts of it were designed so that the engine could be produced on a quantity basis. It is shown in *Fig. 55.*

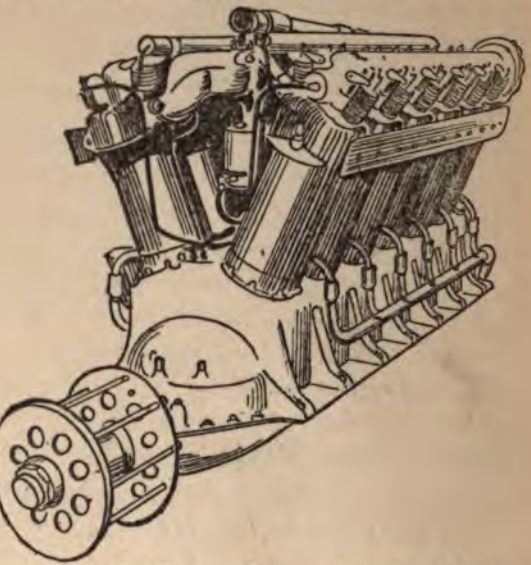

FIG. 55. THE FAMOUS LIBERTY AIRPLANE MOTOR

The final perfected Liberty engine was the most powerful one ever built for airplane work; it developed upwards of 500 pounds and its weight was about 800 pounds. This engine was completed at the *Packard Motor Car Company's* works in Detroit, Mich., on July 3, 1917, and it was rushed to Washington, arriving there the next day—the 4th—and this is how it came to be named the *Liberty* motor.

Both the *scupper* system of lubrication, that is one in which a projecting spoon on the crank-web throws the oil in the crank-case up on the bearings, and the *force feed* system was tested and the latter was finally adopted.

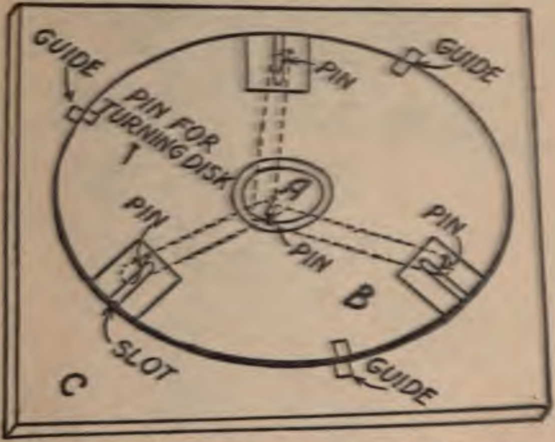

Fig. 56.—A. How the Gyro Engine Works

Several ignition systems were tried out, but the *Delco* was the one which proved the most satisfactory. In this system a small dynamo is used to generate the current, and after it is *stepped up* by spark coils it is passed on to the spark-plugs by distributors.

The Gyro or Revolving Engine.—In this type of

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engine, the cylinders revolve around the shaft and, curiously enough, there is no to and fro motion of either the cylinders or the pistons, but each of these turns round a different center. The pistons are connected by their respective connecting rods to a hub and this in turn is fixed to a shaft.

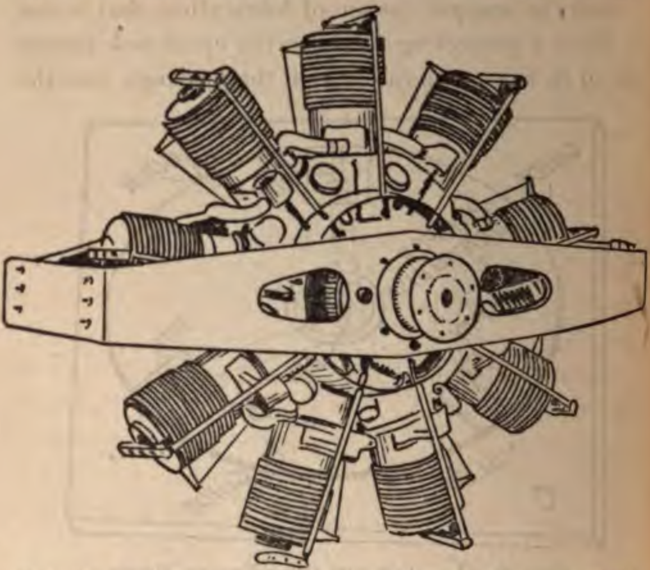

FIG. 56.—B. THE GYRO AIRPLANE ENGINE MOUNTED IN ITS FRAME

The cylinders, which radiate from the hub like the spokes of a wheel, turn round on it, and instead of the pistons rotating the shaft, the explosions of the fuel charges act on the pistons and these turn the shaft instead. The action of the gyro engine will be understood from the diagram *A* in *Fig. 56,* while the engine complete is shown at *B.*

The Cooling Scheme.—Gyro engines are air cooled, that is, the cylinders have paralleled metal rings on them to dissipate the heat exactly like air-cooled motorcycle engines. They are, therefore, lighter in weight for the horsepower developed than engines with water-cooled stationary cylinders.

The Use of the Muffler.—Before the war, airplane engines were not provided with mufflers, but during the war they were used because the noise of the exhaust had to be reduced to a minimum so that the enemy could not hear the planes when they were approaching.

Self-Starters for Engines.—The latest airplane engines are equipped with self-starters. As it would not be practical to use storage batteries because of their great weight and since they contain a liquid, starting motors operated by compressed air are used instead.

CHAPTER VI

THE ECONOMICAL OIL ENGINE

Since gas is not always at hand and gasoline is quite an expensive fuel, makers of internal combustion engines turned their attention long ago toward using cheaper fuels, such as kerosene and even crude oils, and their efforts along this line have been highly successful.

Fuel oils are the cheapest kinds you can buy, but kerosene is the best of the fuel oils, especially for small engines, and as it costs only about one-half as much as gasoline and only about one-half the amount is used for the power produced, it is very economical, you can see.

Difference Between Oil Engines and Gasoline Engines.—Stationary, portable, and mobile oil engines are built in all sizes, but the last named type is used only for marine and traction work.

They are made in both the two and four stroke cycle kinds, the two cycle engines being largely used because they do away with the valves in the cylinder and this gets rid of the camshaft, gears, and other accessories that are always found on four cycle engines.

Again, *mixing valves* are used on oil engines very similar to those on stationary gasoline engines, and this makes for simplicity as against the more complicated carburetors that are a part of all mobile gasoline engines.

Further, many oil engines, especially the larger sizes, are of the Diesel and semi-Diesel types, that is, the fuel charge is fired either by the heat developed by compression of air alone or by the heat of the explosion which keeps a hot ball, or bonnet, at a temperature high enough to fire the fuel charge. Either of these simple expedients gets rid of a lot of ignition trouble.

Finally a spray of water is sometimes injected into the cylinders at the same time that they take in air, and the valve for the water so used will be considered presently.

Oil Fuel Feed System.—*The Oil Supply Tank.*—In very small engines the fuel tank often sets close to the cylinder and the oil is drawn into the latter through a nozzle by the suction stroke of the piston.

In some engines, up to 20 horsepower, the fuel tank is placed in the base and is large enough to hold a sufficient quantity of oil to run the engine for a stretch of 24 hours, and, where the rules of the *Fire Underwriters* will permit, there is no danger in using an oil supply of this kind. For engines of more than 20 horsepower it is better in every way to have a large storage tank outside of the engine and sunk in the ground.

In either case the oil from the supply tank is forced into a small auxiliary fuel tank close to the engine by (1) a *simple plunger pump,* (2) by an *air compressor pump,* or (3) by a *vacuum formed* by the *suction stroke of the piston* in the cylinder of the engine.

Why Fuel Mixing Valves and Injectors are Used.—No carburetor has yet been invented which can successfully break up kerosene, or the heavier fuel oils, into a spray so that it will mix with air before it enters the cylinder except that these oils are highly heated first.

When a fuel oil is *preheated* for this purpose it must not cool down between the carburetor and the cylinder, and so the air must also be heated before it enters the cylinder. But when the air is preheated it expands and this decreases the weight of it, and consequently of the fuel charge, with the result that the engine drops in power.

For this reason the kerosene, or other heavy fuel oil, is *sucked* or *injected,* as the case may be, through a nozzle into the cylinder.

Types of Fuel Nozzles.—There are two distinct types of fuel nozzles used on oil engines, namely, those in which (1) the oil and air are drawn by suction through the same nozzle, when it is called a *mixing valve,* and (2) the oil alone is forced by pressure through the nozzle, when it is called a *fuel injector.*

Kinds of Mixing Valves.—*A Simple Mixing Valve.*—The simplest kind of a mixing valve is merely a nozzle through which the fuel oil and air are drawn at the same time by the suction stroke of the piston.

When the fuel oil and air are drawn into the cylinder, the oil is broken up into fine particles by striking the inlet valve, or some other metal surface inside the cylinder, when it mixes with the air; the heat of the cylinder then vaporizes it, when it makes a suitable fuel mixture. This is the kind of a mixing valve that is used on the *Delco-light* oil engine, and is shown in *Fig. 57*.

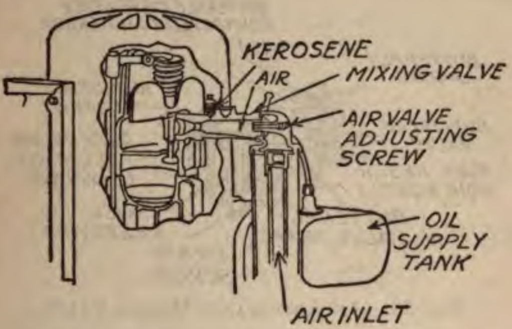

FIG. 57. A SIMPLE FUEL MIXING NOZZLE

An Adjustable Mixing Valve.—In this kind of a mixing valve a needle valve fits into the nozzle, so that the amount of fuel oil admitted into the cylinder can be regulated. The kind used on a Fairbanks-

Morse engine is shown in *Fig. 58.* The air is taken in through a separate inlet valve.

The oil vapor and the air mix in the chamber just above the valve, and the fuel mixture then goes into the cylinder of the engine. The inlet pipe of the needle valve opens into an overflow cup, or *fuel reservoir,* as it is called, that is, the oil is pumped into the fuel reservoir from the supply tank, and when the oil reaches a certain level the surplus flows back into the supply tank.

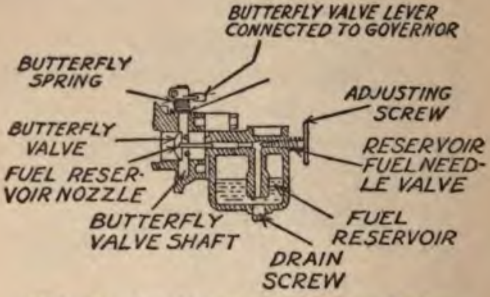

FIG. 58. AN ADJUSTABLE MIXING VALVE

The Fuel Injection Nozzle and Fuel Injection Pump.—In large oil engines a *fuel injection nozzle,* see A and B in *Fig. 59*, is generally used, and this is screwed into the head of the cylinder.

The end of the nozzle has a very small hole in it, and the fuel oil is injected into the combustion chamber at the proper time by means of a *fuel pump.* The nozzle breaks up the oil into a spray, and this is the first stage in converting it into a fuel gas, the next and final stage taking place when the heat of the combustion chamber completely vaporizes it.

The better made nozzles have a *spring cut-off* valve inside of them to prevent the oil from dripping into the combustion chamber after the pump stroke has been made which injects the oil through the nozzle.

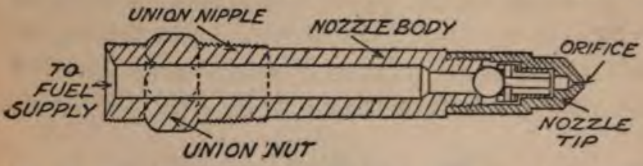

FIG. 59.—A. CROSS SECTION OF A MUNCIE FUEL INJECTION NOZZLE WITH UNION JOINT

The *fuel injection pump* is usually of the *plunger* and *check ball type,* as shown in *Fig. 60.*

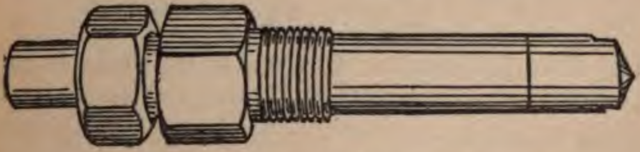

FIG. 59.—B. MUNCIE FUEL INJECTION NOZZLE

The stroke of the plunger takes place when the piston of the engine is making the last stretch of its compression stroke, and as the combustion chamber is the hottest at the end of the stroke the oil is made into a thoroughly dry gas, and hence but little carbon is left behind.

The Use of Water in Oil Engines.—In some oil engines, especially those built in the larger sizes, a spray of water is sucked, or is injected, into the cylinder with the fuel charge.

To break up the water into a spray a nozzle is used, and the size of the *orifice,* as the hole in the end of it is called, is usually controlled by means of a needle valve exactly like those used for converting fuel oil into a spray. Of course, the instant the spray of water enters the hot cylinder it is changed into live steam.

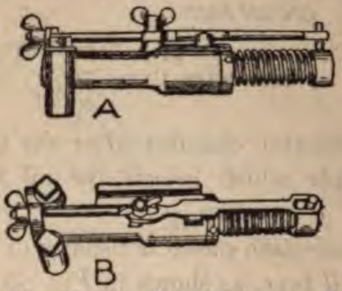

FIG. 60. MUNCIE FUEL INJECTION PUMP
A, Side View of Pump. B, Top View of Pump.

The scheme of using water in most oil engines is to soften the force of the explosions, when it acts in part like a steam engine, that is, it makes the expansive force more continuous. In engines where a *hot-ball igniter* is used a spray of water injected into the cylinder prevents the fuel charge from exploding prematurely, that is, before the piston has reached the end of its compression stroke, and this it does by keeping down the heat of the cylinder. A water spray is not needed for this purpose where an electric ignition system is used.

Another good feature about using a water spray is that it helps to change the oil into a gas, and when the steam comes in contact with the white-hot particles of carbon a chemical change takes place and *water gas*, or *producer gas*, as it called, is made.

Now water gas is formed of two gases, namely, *carbon monoxide* and *hydrogen*, and both of these burn, hence the carbon is used up in making them, and this prevents it from being deposited in the cylinder, where it *scores* the walls of the latter, makes the engine *knock, back fire* and lose power.

The bad thing about using a water spray, especially in small engines, is that it leaves a deposit in the combustion chamber if it is *hard water*. This untoward condition can be prevented by using *rain water* or *distilled water*. Again, where a water spray is used in a small engine the wear is very hard on both the cylinder and the piston, and this shortens the life of the engine. Finally, where a water spray is used the exhaust pot and exhaust pipe get clogged up with sediment, and it must be kept clean or the engine will not give its full rated horsepower.

Kinds of Ignition Devices.—Two kinds of ignition schemes are used for firing oil engines, and these are (1) the *hot-ball igniter*, or a modification of it, and (2) the *electric jump-spark* system.

The Hot-Ball Igniter.—Engines that are fitted with hot-ball igniters are called *semi-Diesel engines,* because the heat for firing the fuel charge is developed by the heat of the burning charge after the ball is heated by a gas, or a kerosene burner.

The hot-ball igniter consists of a hollow iron ball which sets in the head of the cylinder, as shown in *Figs. 61, 62* and *63.* To start the engine a cap, or plate, is taken off of the cylinder head, which exposes the hot ball and the latter is then heated by a gas, or a kerosene blow torch flame. When the ball is red-hot the blow torch flame is removed, the cap or plate is put on the cylinder head and the engine is started.

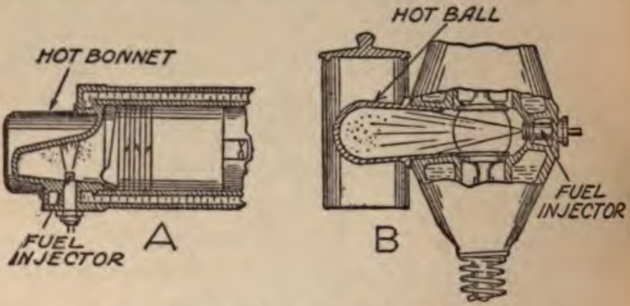

Fig. 61. Kinds of Hot-Head Igniters

A, Bessemer Bonnet Type, Side View of Cylinder. B, De La Verne Hot-Ball Type, End View of Combustion Chamber.

Now when the air is being compressed on the compression stroke it fills the hot ball and when it is fully compressed the fuel oil is injected into it and the hot air not only furthers the process of making a gas out of the oil but it fires the fuel charge as well.

The Hot Bonnet Igniter.—Because carbon collects in the ball and has to be cleaned out to prevent it from interfering with the ignition of the fuel charge, an improved form was devised. This was done by cutting away about half of the ball, which made a bonnet out of it, as shown in *Fig. 61*, at *A.*

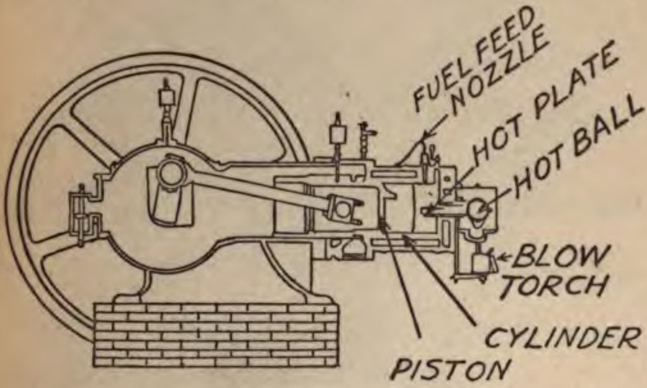

FIG. 62. CROSS SECTION VIEW OF AN EARLY MUNCIE OIL ENGINE SHOWING HOT-BALL IGNITER

The ignition bonnet is heated by a torch before the engine is started in exactly the same way as the ball igniter, after which the heat of the exploding fuel charge keeps it hot enough to ignite the following charge.

Jump Spark Igniters.—Three kinds of electric jump spark systems are used for firing the fuel charges of oil engines, and these are (1) the *battery* and *jump spark coil* with *spark plug;* (2) the *rotating high tension magneto with spark plug,* and (3) the *low tension oscillating magneto* with *make and break* spark. All of these ignition systems have been explained in Chapters II and IV.

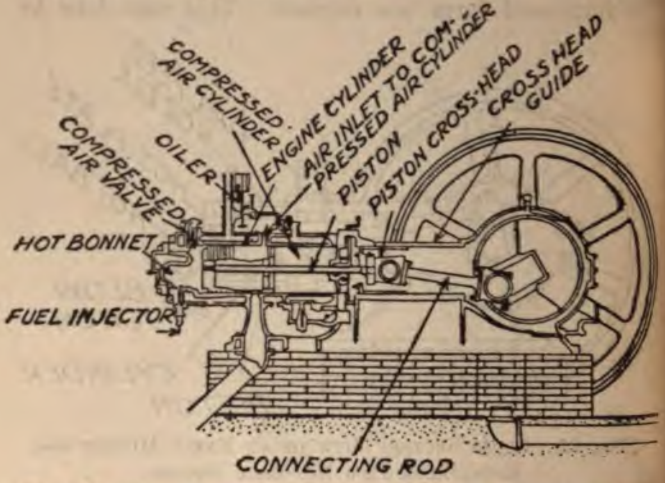

FIG. 63. CROSS SECTION VIEW OF A RECENT BESSEMER CRUDE OIL ENGINE

How the Governor Works.—With a small high-speed oil engine whose crankshaft is coupled direct to the shaft of a dynamo and which is used only for charging storage batteries, a governor is not needed, but with oil engines that are used for running different kinds of machines where the load varies a *governor* is necessary.

Many oil engines whether small or large are fitted with govenors of the *centrifugal shaft type,* that is, there is a weight which is pivoted to the flywheel, as shown in *Fig. 64.* The flywheel is *keyed* to the crankshaft, and the inside part of the eccentric, or *sheave,* as it is called, is also keyed to the shaft; the *strap* of the eccentric, which is the outside part of it, is pivoted to the eccentric rod.

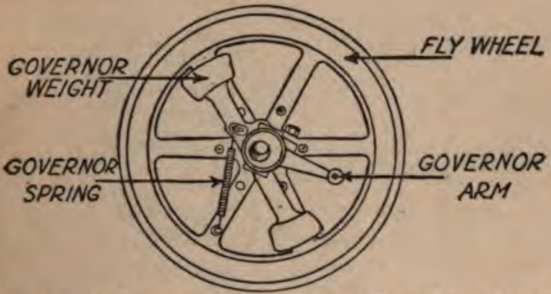

FIG. 64. FLYWHEEL GOVERNOR OF A FAIRBANKS-MORSE ENGINE

Now, when the engine is running and the flywheel gets to going too fast the weight which is lighter begins to move faster and catches up with the speed of the wheel. In so doing it moves the eccentric rod down, and this gives the eccentric rod a shorter *throw,* that is, a shorter to and fro movement.

Conversely, when the flywheel begins to slow down the weight cannot keep up with it, and this moves the eccentric rod up, which makes the throw of the eccentric rod longer. Having proceeded this far with the governor, let us see now how it controls the speed of the engine.

In small oil engines the eccentric rod of the governor is connected with a butterfly valve which is pivoted in the inlet pipe that connects the fuel chamber with the cylinder, as described in Chapter III. But in large oil engines the eccentric rod is coupled to the plunger rod of the fuel pump, as shown in *Fig 65.*

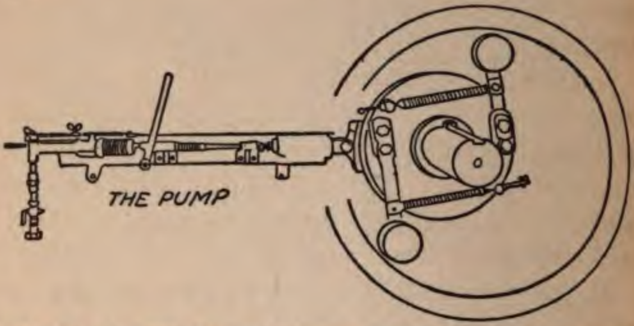

FIG. 65. A FUEL PUMP CONNECTED TO A MUNCIE FLYWHEEL GOVERNOR

It is easy to see now that when the length of the throw of the eccentric rod is greater or lesser than normal the length of the stroke of the plunger of the fuel pump is varied so that when the engine tends to run too fast only a little fuel oil is pumped into the cylinder and when the engine begins to slow down a larger amount of oil is pumped into the cylinder.

Of course, there are a lot of little refinements in the governor, such as springs and *dash pots* to check the too sudden action of the weight, and adjustments on the pump, so that the speed of the engine can be varied by the engine tender while the engine is running. An oil engine with a governor and pump built on this principle not only makes the speed of the engine steady but is very economical of fuel.

About Cooling Cylinders.—The only oil engine that I know of which is *air-cooled* is the little high speed *Delco-light,* all the others of whatever size and type, being water cooled.

In the first named a draft tube sets over the cylinder of the engine; the top of it is open and the lower part connects with a housing around the flywheel which is built like a fan. When the engine is running the fan sucks the air down through the draft tube and out into the open air.

In some oil engines the end of the cylinder in which the explosions take place, or *combustion chamber,* as well as the cylinder itself is jacketed, that is, they are surrounded by spaces through which the water circulates, and in this way the heat of the whole cylinder is kept down to as low a temperature as it will operate with.

Since a lot of heat is needed to convert heavy fuel oils into gas, some oil engines are made with the heads of the cylinders exposed directly to the air. In *hot-head engines,* as these are called, the fuel oils are exploded at a very much higher temperature than in engines with water-cooled heads, and in this way the carbon is burned up.

In some of the larger engines water is injected into the cylinder, not with the idea of preventing premature explosions, but to keep down the temperature.

The circulation of water around the cylinders is done in the same ways as those used for gas engines and stationary gasoline engines.

The Lubrication of Oil Engines.—The same schemes are used for lubricating oil engines that are employed for gas and stationary gasoline engines, that is, the upright engines have the *splash system* and the horizontal engines are fitted with the *mechanical force feed system.*

Where force feed lubrication is used the oiler is worked by the camshaft so that the amount of oil supplied depends on the speed of the engine and this means economy in lubricating it.

A Word on Fuel Oils.—*Kinds of Fuel Oils.*—Small engines run better on *kerosene* than on heavier oils, but the larger heavy-duty engines work well on what is called *crude oils.*

There are a couple of dozen names for various kinds of fuel oils, but the following will serve to show the general difference between them. Crude oil is the oil right from the oil wells, and this used to be the cheapest kind of fuel oil you could buy, but the distillates are more generally used at present.

When crude oil is *refined,* which means that it is *distilled,* a number of fuel oils are given off and the *gravity,* that is, the density, of these is different, and the *flash points* are also different.

The name *distillate* is given to any kind of oil which is obtained by refining crude oil. When crude oil is refined *benzine* passes off first, then *gasoline* and next *kerosene.* Gasoline is called *petrol* in England, and on this side low grades of gasoline are called *naphtha* and *motor spirits.*

Kerosene, or *coal oil,* is heavier than gasoline, and when it is bleached white and has a high enough flash point it is used in lamps for lighting. When it is of poor quality and colored it is called *solar oil,* and when it is of a still poorer quality it is called *engine distillate.* *Gas oil* follows kerosene when crude oil is distilled and so, of course, it is heavier.

Fuel oils, in the strict meaning of the term, include all kinds of oils that do not need to be refined to burn. *Tops, bottoms, residuum, stove oil* and *star oil* are all cheap oils. Other oils made from coal tar and the *by-products* obtained from city gas plants can also be used for fuel for oil engines, while *alcohol,* where it can be bought cheaply enough, makes an admirable fuel.

Kind of Fuel Oil to Use.—Use kerosene only in engines where the makers specify this kind of fuel oil. For regular oil engines the fuel oil can be of any kind provided that it has (1) a flash-point below 275 degrees *Fahrenheit,* by what is known as the *open cup test;* (2) a specific gravity not lower than 26 degrees, *Baume;* (3) it should contain not more than ½ per cent of sulphur; (4) contain not more than ½ per cent of water, and (5) not more than 3 per cent of coke. Finally, at least 60 per cent of the oil must pass off when it is distilled at or below 680 degrees Fahrenheit.

CHAPTER VII

THE DIESEL SELF-IGNITING ENGINE

You will remember I told you in the first and second chapters about how the Diesel oil engine fired its fuel charge by compressing the air in the cylinder, which raised its temperature, and you know that all other types of internal combustion engines use some kind of an igniter for this purpose.

Now, while this difference in the methods of ignition between the Diesel and other oil engines is the most important one, there are several other factors that are found in the former which are of interest, and these will be described in due time as we push along.

If you ever had anything to do with a gasoline or oil engine or drove a motor car you know that when the engine is running at low speed with the throttle wide open and the engine is laboring under an excessive overload it will begin to *knock,* and this is caused by *premature ignition.* Now, premature ignition has long been a great problem in building internal combustion oil engines, and it was only solved when Diesel invented the engine now under discussion. The Diesel engine is the most economical engine that has yet been made for producing power where crude fuel oils can be had to run it.

Diesel engines are built in both the vertical and the horizontal types, have one or more cylinders, and are made on both the two and four stroke cycle principles.

How the Diesel Four Stroke Cycle Engine Works.—In this engine the cycle of operations is as follows: (1) on the *suction stroke* the air inlet valve opens and air is drawn into the cylinder; at the end of the suction stroke the inlet valve closes, and (2) on the *compression stroke* the piston compresses the air to upwards of 500 pounds to the square inch, and this raises the temperature to about 1,000 degrees *Fahrenheit,* which is far above the ignition point of the heaviest fuel oils.

Just before the end of the compression stroke, the fuel valve is opened and the fuel oil, which is injected under pressure into the cylinder in a fine spray, instantly catches on fire; then (3) the *power stroke* begins, and the spray of fuel oil is injected during about $\frac{1}{10}$ of the length of this stroke.

Hence, the oil *burns* instead of exploding, as in gas and gasoline engines, and the result is that the temperature of the fuel is kept about the same and the pressure on the piston is more nearly uniform throughout the length of the stroke instead of being set up by a sudden blow, as in an ordinary gas or gasoline or oil engine. This makes the engine run smoother and gives it more of the steady pulling quality of the steam engine.

Finally (4) the exhaust valve opens on the *exhaust stroke* and the burnt gases are pushed out of the cylinder into the open air, as in any ordinary four stroke cycle engine.

How the Diesel Two Stroke Cycle Engine Works.—The action of a Diesel two stroke cycle engine is very like that of an ordinary engine of the same type, that is, the exhaust of the burnt gases, the admission of fresh fuel oil and the ignition of the latter all take place during a single stroke.

The cycle of operations is this: (1) on the first, or *compression stroke,* the piston compresses the air that is in the cylinder just as it does in a Diesel four stroke cycle engine to about 500 pounds per square inch, when the temperature of the latter rises to about 1,000 degrees *Fahrenheit.*

Then (2) on the start of the second stroke the fuel valve is opened, the oil is injected into the cylinder, when it is fired and then the power stroke takes place. When the piston is near the end of its stroke both the air inlet and the exhaust valves are opened at the same time; the air rushes in and pushes out the burnt gases so that when the compression stroke is made only fresh air remains in the cylinder.

The Construction of the Diesel Engine.—*The Valves of a Two Stroke Cycle Engine.*—A two stroke cycle Diesel engine has two *poppet valves* in the head of the cylinder, and these are (1) the *fuel* *admission valve* and (2) the *air starting valve,* which is used to start the engine. The *air inlet valve* and the *exhaust valves* are opened and closed by the piston itself as in the ordinary two stroke cycle engine which I described in Chapter II.

The Valves of a Four Stroke Cycle Engine.—While an ordinary four stroke cycle engine has only a fuel inlet valve and an exhaust valve, a Diesel engine of the four stroke cycle type has four and sometimes five poppet valves, and these are (1) the *air inlet valve,* (2) the *fuel injector valve,* (3) the *exhaust valve,* (4) the *air starting valve* and (5) a *safety valve.*

How the Valves Work.—The valves of both the two stroke and the four stroke cycle engines are worked by levers or cams which are operated by gears driven by the crankshaft.

The fuel valve is formed of a needle valve fitted in a nozzle which has a very small opening in it like those described for the larger makes of oil engines in the preceding chapter.

Since the compression stroke compresses the air in the cylinder the fuel oil must be injected into the air charge by a blast of air which is under a much higher pressure, and to do this an air compressor pump, called an *injector pump,* is used.

In the original Diesel engine[1] the needle valve sets upright in a little cylindrical fuel reservoir which has a small hole in the bottom of it; the fuel reservoir is fixed in the cylinder head and is connected to the injector pump by a pipe.

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[1] U. S. Patent No. 542,846 granted to Diesel explains this fuel valve fully. You can get it by sending five cents in coin to the *Commissioner of Patents,* Washington, D. C.

When the pump makes its suction stroke it pulls a small amount of fuel oil into the reservoir. The *lift* of the needle valve is regulated by the governor, which determines the length of time and the distance it is opened, and, hence, the amount of oil that is pulled into the reservoir.

The instant the needle valve opens, the fuel oil in the reservoir is driven in a fine spray into the compressed air charge in the cylinder by the blast of high pressure air, when it ignites.

The Air Compressor, or Injector Pump.—This pump is generally a built-in part of the engine, and is driven by a crank on one end of the crankshaft, as shown in the side cross-section view *Fig. 66* and end cross-section view *Fig. 67*.

The air compressor is of the two, or three stage type, that is the air is compressed twice and sometimes three times by a succession of pistons and cylinders, each succeeding one being smaller than the other. The one shown in *Fig. 66* is a two stage air compressor.

The pressure of the air needed to spray the oil into the red-hot air charge in the cylinder of the engine is between 800 and 1,200 pounds to the square inch, the pressure depending very largely on the nature of the fuel oil that is used. The air com-

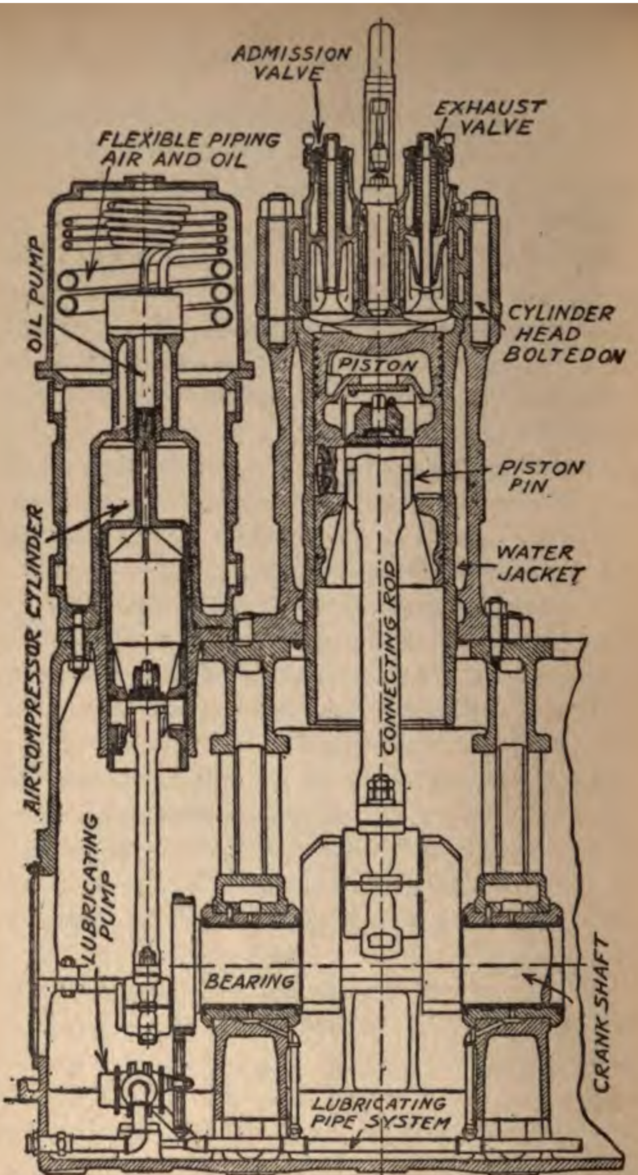

Fig. 66. Longitudinal Cross Section View of a Single Cylinder Diesel Four Stroke Cycle Engine Showing a Two Stage Air Compressor

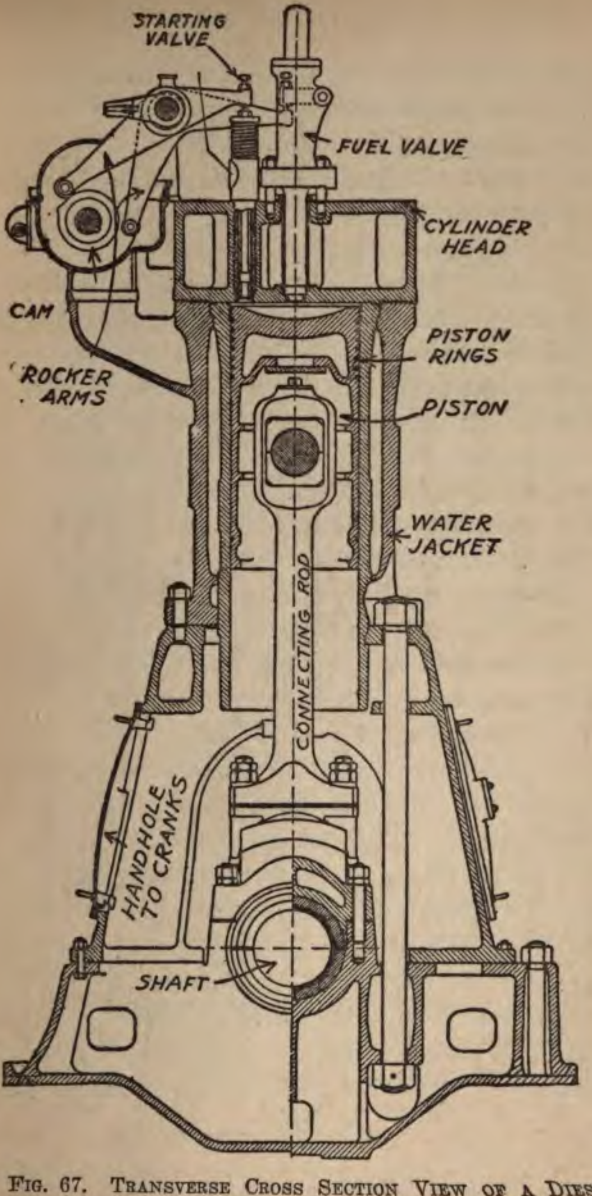

FIG. 67. TRANSVERSE CROSS SECTION VIEW OF A DIESEL ENGINE

pressor when in operation takes from 4 to 7 per cent of the total horsepower of the engine to run it.

The Scavenging Pump.—With a two cycle engine a blast of air, called *scavenging air,* must be used to drive the burnt gases out of the cylinder.

The scavenging air, which is under a low pressure—usually from 4 to 8 pounds per square inch—is generally obtained from the low pressure cylinder of the air compressor, but in some Diesel engines a separate scavenging pump is belted to the engine.

Again, in some engines the valve which admits the scavenging air to the cylinder is a port opened and closed by the piston sliding across it, while others have a poppet valve in the head of the cylinder.

This latter kind of valve gives the best results for the scavenging air is then forced from the top of the cylinder, clear through it and then out of the exhaust port at the other end, and this thoroughly cleans out the burnt gases.

While it only takes about 4 per cent of the power developed by the engine to supply the scavenging air, where the cylinder is so scavenged there is a great saving effected in the use of the fuel oil, and at the same time there is a larger output in power. The reason for this higher efficiency is found in the fact that but very little of the burnt gases remains behind to contaminate the fresh fuel mixture.

Governors for Diesel Engines.—There are three distinct kinds of governing devices used on Diesel engines, and these are (1) by controlling the time the suction valve is open, (2) by varying the length of the piston stroke of the fuel injector pump, and (3) by varying the clearance of the pump.

The purpose of the governor is, of course, to give close regulation, and any of the governors described will serve to regulate the speed of the engine close enough for running dynamos, provided it has two or more cylinders.

How a Diesel Engine Is Started.—Since a Diesel engine must be running before it will develop enough heat to ignite the fuel charge, some means for starting it must be used.

The usual way to start a Diesel engine is to admit air which has been previously compressed in a tank to about 250 pounds to the square inch into the cylinder of the engine through the *starting valves,* of which there is one to each cylinder.

Before the engine is started a *clutch* is thrown in by a lever and this throws the cams that operate the fuel valves over so that they are *cut out* and the starting valves are *cut in* and the engine is made to run by compressed air. After the pistons have made a few strokes and the flywheel has gathered enough momentum the clutch is thrown out and the cams are moved over so that they again work the fuel valves. As soon as the fuel is injected into the cylinders the engine begins to develop power.

Cooling Schemes for Diesel Engines.—Owing to the high temperatures developed by the Diesel engine not only the cylinder but the cylinder head and, in large sizes, the piston as well must be water cooled. The water is circulated by a force pump and from 3 to 9 gallons are used per horsepower per hour, the amount being determined by the heat developed.

The Lubrication of Diesel Engines.—Since very high temperatures are produced in the cylinders these and the working parts of the engine, such as wrist pins, crankshaft bearings and other bearings in the crankcase, must be oiled with a good quality of lubricating oil having a *medium* body.

For lubricating the cylinders of the air compressor only the best light body lubricating oil should be used. Where only a little lubricating oil is fed into the cylinders of the compressor and the compressed air is well cooled between the successive stages a poor lubricating oil will carbonize and this is the beginning of grief.

But if the intercooling of the air between the compression stages is not good the high temperature and high pressure are very liable to *crack* the lubricating oil, that is break it up and liberate the gases in it when it will burn just like a fuel oil does in the cylinder of an engine. The moral is *use good lubricating oils* and save trouble.

Advantages of the Two and Four Stroke Cycle Diesel Engines.—*The Four Stroke Cycle Engine.*—This type of engine is more economical of fuel than a two stroke cycle engine because the expansive force of the burning fuel charge does not stop until the end of the power stroke is reached. Again, no scavenging pump is needed to force out the burnt gases, and this also saves power.

The cylinders are not heated to so high a temperature because the fuel oil is ignited only once in every four strokes, as against once in every two strokes in a two stroke cycle engine. All of the burnt gases are forced out of the cylinder of a four stroke cycle engine on the exhaust stroke, while in a two stroke cycle engine it is quite impossible to get all of the waste gases out.

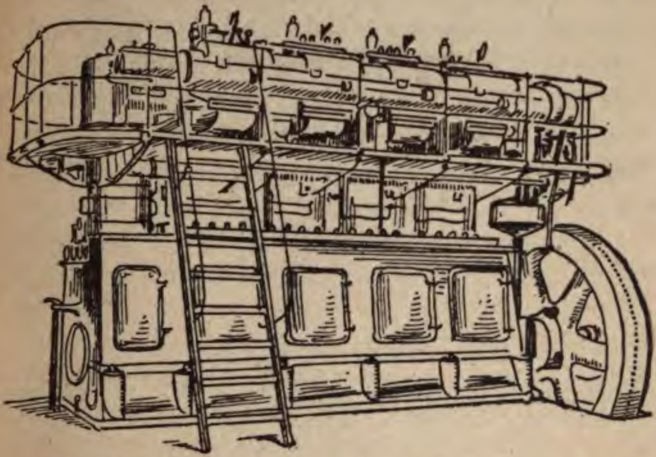
FIG. 68. AN UPRIGHT 400 H. P., FOUR CYLINDER, FOUR STROKE CYCLE DIESEL ENGINE

The Two Stroke Cycle Engine.—Since every other stroke is a power stroke in a two stroke cycle engine the power developed is nearly twice as great as in a four stroke cycle engine having the same size cylinder and length of stroke.

This makes the weight of the engine lighter for the same horsepower, and as a two stroke cycle engine has fewer parts it is easier to move about, set up and keep in repair than one of the four stroke cycle type. Engines under 700 horsepower are often of the four stroke cycle type, but where they are over the above-named horsepower they are generally of the two stroke cycle type. *Fig. 68* shows an upright, four cylinder, four stroke cycle, 400 horsepower Diesel engine.

CHAPTER VIII

HOW TO PRACTICE ENGINE ECONOMY

If the hoary and bewhiskered adage which tells us that an "ounce of prevention is worth a pound of cure" was stenciled on the side of every internal combustion engine sold and those who buy them would heed the world old saying, there would be at least 50 per cent less of them go to the scrap heap every year.

A man who has had little or no experience with machines in general and engines in particular is apt to think because a power unit of this kind is made of iron and steel all he needs to do is to feed it with fuel, lubricate it with oil and give it water once in a while and that in turn it will deliver power without further attention.

And so an engine will run for a while, sometimes a long while, under these conditions, but to get it to develop its full rated power and, what is of even more importance, keep it in service for the longest time, there are some other things that must be looked after and diligently, too, for using the right kind of fuels and lubricating oils and keeping an ever-watchful eye on the engine are the big factors that count for economy.

About Fuel Economy.—*Gas Fuels.*—The difference in the prices of *natural, producer* and *city gas* is not of such great importance when you are running a small engine. Of course, if you are living in a region where there is natural gas, by all means use it, but if not, use city gas, unless you are running an engine of 40 horsepower or over, and then it will pay you to install a *suction gas producer.*[1]

Gasoline, Fuel Valves and Carburetors.—In mobile engines such as those used for running motorcycles, motor boats, motor cars and airplanes, it spells economy to use a good uniform grade of gasoline, and the only way to get it is to buy it of the Gulf, Texas, Standard Oil or other good company.

In stationary engines, especially those of large size, the quality of the gasoline can be of a lower grade than that used in mobile engines. Before using gasoline it is a good scheme to filter it through a piece of chamois skin or, where it is used in large quantities, strain it through a piece of wire gauze having a fine mesh. Foreign particles of matter that get in the gasoline will clog up the fuel valve or carburetor, and this will cost you both time and money.

Where a fuel valve is used on a gasoline engine it is adjusted to a nicety before the engine leaves the factory, and it will not need readjusting unless something gets in the gasoline and chokes up the needle. But with a carburetor it is different, and it is up to you usually to see that it is properly adjusted to mix the gasoline and air in the right proportions.

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[1] For data concerning gas producers write to the Otto Gas Engine Works, Philadelphia, Pa.

If the fuel valve or carburetor gets out of adjustment your engine will lose power and it then becomes very wasteful of fuel. To get either of these devices adjusted exactly right, it takes a man who thoroughly understands the particular make your engine is fitted with. You can learn to make these adjustments yourself if you have the time and the patience of Job, but don't let any alleged engine mechanic fool with it unless you know that he knows just what he is about.

Kerosene and Crude Oils.—In oil engines having electric ignition kerosene gives better results than crude oils, because the cylinder is not kept hot enough to vaporize lower grade oils without leaving a lot of carbon behind.

In buying kerosene for your engine don't get the highly refined illuminating oil that has a fire test of 140 to 150 degrees *Fahrenheit,* but take the lower grade kerosene, whose fire test is 100 to 110 degrees *Fahrenheit.* There are several reasons why the latter is better than the former, and among these are because (1) it ignites at a lower temperature, (2) it evaporates easier, and (3) it is very much cheaper.

Heavier fuel oils such as solar, gas and even crude oils can be used successfully in engines which are fitted with hot ball or bonnet igniters and hence these engines are very economical to run. The very cheapest crude oils as they come from the wells can be used in Diesel engines because the temperature of the cylinder is even higher, hence this type of engine is still more economical to operate.

Always filter the fuel oil you are using to get all of the grit out of it, for solid matter, however finely divided, in either a gas or a liquid fuel, is very apt to interfere with the lubrication of the cylinder. Finally, buy the fuel oil from a refinery which has distilled the gasoline out of it and by so doing you can run your engine for the least amount of money possible.

To Lubricate Economically.—Far more important from the standpoint of economy than the use of the right kind of fuel in an engine is the lubrication of it.

In all high speed engines of the mobile type, except those built for airplanes, light and medium body mineral oils give the best service. In airplane engines castor oil is employed, and though it is a vegetable oil it is the heaviest oil known. Other than castor oil no vegetable oils or animal oils can be used for lubricating engines.

Heavy duty engines require an oil with a heavier body than those built for lighter loads. The chief difficulty with heavy oils is that they offer a higher resistance to the moving parts, and that they are very apt to leave a deposit of carbon; on the other hand, an oil with too light a body is liable to burn up, and when this happens carbon is also left behind. If you can get an oil of just the right body for your engine you are practicing engine economy that is truly worth while.

In buying lubricating oil just bear in mind that the higher the temperature of the cylinder walls and the heavier the load the engine has to carry the heavier the lubricating oil should be, and the other way about.

Nearly every maker specifies the kind of lubricating oil that gives the best results with his particular engine, and if possible get the kind he names and stick to it. Never buy an oil because it is cheap, for cheap oil is poor oil, and poor oil does not lubricate, but it burns and forms carbon, makes the valves and the piston rings stick and causes the open end of the cylinder and the exhaust pot, or muffler, to smoke. In fact, a fellow's got to have more money than sense in order to be able to afford to use poor oil.

If you are in doubt as to the kind of lubricating oil your engine needs, write to the *Vacuum Oil Co.,* 100 Broadway, New York, or to the *Platt and Washburn Refining Co.,* 11 Broadway, New York, and either company will tell you the best and most economical oil to use.

How Water Economy Is Had.—Next to air, water is the cheapest thing an engine uses, but don't let yourself believe that all water is alike, or that any kind will do.

Where water is used inside of the cylinder to prevent preignition or to keep down the temperature, the water must be free from lime, for this will do a lot of damage. To prevent it use either rain water or rig up an apparatus for distilling it.[1]

In stationary engines, where water is circulated around the exhaust, the heat will cause the solid matter in it to be deposited, and the water spaces will finally choke up. When this happens the exhaust valve may burn out and a new one will have to be put in. This not only costs money, but you will have to shut down your shop while it is being done.

To prevent this untoward occurrence, make a solution of 1 part of *muriatic acid* and 19 parts of soft water. Now draw off the water from the cylinder cooling spaces every fortnight and fill them with the acid solution. Let the solution stay in over-night, but not longer, or it will act on the iron. The acid solution will soften and break up the lime, and you must then wash it out with clean water.

Where stationary and portable engines are run in winter and there is the slightest danger of freezing, let the water out of the jacketed cylinders and from the tank, or hopper, where these are used, every night.

In a motor car or other mobile gasoline engine the water must be strained before it is put into the radiator whenever you fill it. Drain off the old water once a month and fill it with clean water. Every three months wash out the water spaces and radiator with a hose and finally clean out the water jackets with a hose every year.

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[1] A simple water still is described in *The Home Handy Book* by the present author and published by D. Appleton & Co., New York.

For mobile engines where the temperature does not drop to more than 10 degrees below 0 *Fahrenheit* in winter use an *anti-freezing solution* in the radiator, made of 25 per cent of wood alcohol, 15 per cent of glycerine and 60 per cent of water.

To Secure Ignition Economy.—*Electric Ignition.*—To secure economy at the ignition end of an engine you must see (1) that the battery does not run down or get weak; (2) that the magneto gives a spark at least 1/8 inch long, (3) that the spark contacts or the points of the spark plugs are clean and where the latter are used, that the spark points are separated the proper distance,[1] and (4) that the timer is in adjustment.

Where a *wipe spark* is used, if there is too much tension on the platinum electrode it will wear out quickly, and platinum to-day is worth twice as much as gold. Do not use lubricating oil to oil the bearing of the movable electrode, but use kerosene instead. The kerosene cuts the carbon and dissolves off the gumming deposit which forms on the electrode.

A *jump-spark* ignition system that will not set up a 1/8 inch spark will cause much loss in power.

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[1] This information the maker of the engine will give you.

If you are using a dry battery, test it every day with *an ammeter,*[1] or if you are using a storage battery, test it out with a *voltmeter.*[2]

Any dry cell that does not show a current output of at least 10 amperes should be replaced with a fresh one. To keep a storage battery in condition you must (1) keep the plates covered with the solution, or *electrolyte,* as it is called; (2) see to it that the battery is always fully charged, and (3) that it has a *specific gravity* [3] of from 1.275 to 1.300 *Baume.*

If your engine is fitted with a magneto and it fails to give a spark ⅛ inch long send it back to the manufacturer. But just bear in mind that (1) the armature of a rotating magneto must be turning at its full speed before it will give its full spark length, and (2) that the magneto is the very last part on your engine that is apt to fail in its operation; this being true, be mighty sure that the magneto is really at fault before you ship it back for repairs.

When There Is a Loss of Power.—However little you may know about an engine you will not need to be told when it begins to lose power, and I'll tell you now that when it does begin to lose power you are losing money, so don't let it do it.

What Causes Loss of Power.—There are numerous causes that make an engine lose power, but you can get a line on the trouble if you will remember that all of them, nearly, come under three distinct symptoms, and these are (1) when the *engine works badly,* (2) when the *engine knocks* and (3) when the *engine overheats.*

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[1] An *ammeter* is an instrument for testing the current strength of a battery.

[2] A *voltmeter* is an instrument for testing the pressure, or voltage, of an electric current.

[3] This is easily tested with a *Baume hydrometer.*

Now, when any one of these three things happens you will know that you are paying a big price for a little power, and it is your cue to remedy the defect as quickly as you can, but as this comes under the special heading of *Diseases of Internal Combustion Engines,* and there is more than a little to the subject, I will treat of them in a separate chapter.

The Economy of Cleanliness.—You can always tell a good engineman by the way he takes care of his engine. Keeping an engine clean is not only merely a matter of looks and pride, but it is quite a necessary feature, if the highest economy is to be had.

Wipe all of the exposed parts of the engine with clean waste, either just before you start up the engine or as soon as you shut it down. While it is seldom done, it is a mighty good scheme to have a canvas cover to throw over the engine when it is idle, unless it is a motor car engine, which is protected by a hood, to keep out the dirt and dust.

Be careful that the lubricating oil does not run down on the outside of the engine and onto the top of the foundation, as it will gather dust, and this is almost sure to be drawn into the cylinder with th air, when it will choke up the air inlet valve.

Taking care of an engine is practicing economy just as much as taking care of a gun or a machine of any kind, and an engine that is well cleaned is quite apt to be well looked after in all other respects, hence the economy obtained by cleanliness begets economies in other ways.

What Power Economy Means.—Whatever your requirements for power may be, get an engine that will take care of it when it is running at full load, for the greater the load up to the time that the cylinder begins to overheat the larger will be the saving in fuel, and this means power economy.

That is to say, if you need only 1 horsepower to do the work, don't get a 3 horsepower engine, on the assumption that it will develop 1 horsepower on ⅓ the amount of fuel. As a matter of fact, there is an increase in the fuel consumed in the *reverse proportion* to the power developed in any engine, however small or large, and of whatever type or make.

It is easy to see why this should be so, because the friction of the engine is a *constant,* that is, it always remains the same without regard to the power developed. If an engine could be built which would run without friction, then the amount of fuel consumed per horsepower per hour would decrease in direct proportion to the power developed.

The Upkeep Economy of Your Engine.—As a last word about practicing economy, if you will look after the following several details you will not only get the full rated horsepower out of your engine, but you will get it with the least amount of fuel, the repairs and shutdowns will be few and far between, the interest on the money you have invested in it and the depreciation of it will both be small, and, finally, the life of the engine will be long.

Named, these details are that you must (1) burn the right kind of fuel and see to it that (2) the fuel valve or carburetor is adjusted correctly; (3) the lubricating oil is the best and exactly suited to your engine; (4) the drain cocks are all closed; (5) there is no soot in the exhaust pot or muffler; (7) the gaps of the spark plugs are of the right length; (8) the ignition system is timed correctly; (9) likewise the valves are timed correctly; (10) there is no carbon in the cylinder; (11) the bearings all around fit precisely, and, lastly, (12) that you make a study of your engine, and know exactly how every part of it works.

CHAPTER IX

DISEASES OF INTERNAL COMBUSTION ENGINES

An internal combustion engine of whatever kind or make is very like a human being, in that if it isn't looked after and treated well it will be sure to develop some disease, and so go into an early decline; and sometimes, too, exactly like the mechanism of a man, it will ail and growl around when there isn't a thing on earth the matter with it.

In the foregoing chapter I mentioned that there are three *general* symptoms by which you can tell when something has gone wrong with your engine, but what I did not tell you was that each symptom may indicate any one of a dozen different troubles, and to find the offending one you must know the *specific* symptoms of it.

Now, while it might seem on the face of it to be a pretty hard matter to locate the fault, since there are so many of them—fixing it is easy when you know what to fix—it is not at all a hard job if you go about it the right way, and this is by the process of *elimination.*

When the Engine Works Badly.—*The Seat of the Trouble.*—When the engine works poorly it may be caused by (1) a priming cock that leaks; (2) poor compression caused by a loose or a broken spark-plug; (3) or trouble with the ignition system; (4) gaskets that leak; (5) the use of lubricating oil that has too light a body; (6) piston rings that give too much clearance; (7) piston rings that are bent or are otherwise faulty; (8) a broken lockpin in the piston ring, or (9) valves that do not seat properly.

Finding and Fixing the Fault.—The order I have given above is the one in which you should look for the fault and after testing each one out thoroughly see if the engine works all right or not.

Begin, then, by looking after (1) the priming cocks; if the leak is bad the sound of escaping gases around the loose one will indicate it clearly enough; if there is no sound, squirt a little oil on it where it screws into the cylinder head, and if it leaks little bubbles will rise in the oil.

To fix it try tightening the cock up with a wrench and if you can't get it tight enough to keep it from leaking put a little red-lead on the threads and then screw it up. (2) Sometimes a spark-plug gets a little loose or the threads are worn. To find out whether it leaks squirt a little oil around the threads and watch for the bubbles as explained above. Tighten it up and use some red-lead on the threads if necessary. If the spark-plug is cracked there will be a considerable loss of compression through it, and when this happens you can hear it wheeze, and to fix it all you have to do is to put in a new plug.

(3) When there is no leakage from the spark-plugs or gaskets and the compression seems to be good, examine the ignition system very carefully and look particularly for a *loose wire* or a *grounded wire,* by which I mean a wire that has worked loose in its binding post or one whose insulation has been rubbed off and so makes a slight contact with some other wire or with the engine itself. When you have attended to these details the chances are that your engine will run as well as it did when you bought it, provided you bought a new one.

(4) If the gaskets leak you will know it by the wheezing sounds of the exhaust gases. It may be that the nuts are loose and tightening them will do the business, but do this while the engine is hot.

Should the gaskets be worn out or rotted out, cut new ones out of *asbestos packing*[1] which has a brass or bronze wire mesh in it. When you put on a new gasket smear both sides of it with linseed or lubricating oil and tighten the bolts up when the engine is hot. (5) The next thing to try is a lubricating oil having a heavier body than the one you are using; to do this unscrew the drain plug from the crankcase and run out all of the old oil. This done, screw in the plug and fill the crankcase, or sump, below it, whichever it is, to the oil level with kerosene.

Now run the engine slowly for half a minute or so, when it will clean out the working parts of the engine. Take out the drain plug again and run out all of the kerosene, put back the drain plug and fill the crankcase or sump with the heavier grade of lubricating oil. If nothing else is the matter you will find that your engine will develop more power than you ever gave it credit for.

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[1] The Johns-Manville Co., 41st St. and Madison Ave., New York City, sell it.

After you have attended to all the above easy things, if the compression is still poor, it is then time to conclude that (6, 7 and 8) the piston rings are at fault, or else (9) the valves do not seat as they should.

(6, 7 and 8) To clean, or replace faulty piston rings with a new set, take off the oil shield or crankcase and remove the nuts from the bolts that hold the crank bearings in place. Turn the crank to its outer dead center and you can then pull the piston out of the cylinder. The next thing to do is to clean it with a solution of hot lye and water, then wipe it dry and wash it off with kerosene.

To take off the piston rings raise up one end of one of the rings, slip a strip of tin, about ½-inch wide and 5 or 6 inches long, under it and work it around until it is midway between the ends of the ring. This done, slip another strip of tin under each one, as shown at *A* in *Fig. 69,* when you can easily push the ring from the groove it seats in and off of the piston.

Iron piston rings can be expanded and then slipped over the head of the piston onto their grooves or seats, but do not try to expand *steel* rings. Instead when you put one of the latter on the head of the cylinder press down on one end until it goes into the groove and then screw it around until the whole ring is seated in the groove.

(9) The two chief reasons why valves leak are because (a) carbon gathers in a film on the valve seat and (b) the valves get warped by the heat.[1]

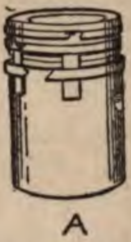

Fig. 69.—A. How to Take Off a Piston Ring

When a valve leaks take off the cylinder head or combustion chamber, as the case may be, and then you can lift out the valve.

The next step is to grind the valve, and this you can do by rubbing a little *grinding paste*[2] on the beveled edge of the valve seat; now set the valve in the seat and turn it back and forth a quarter of a revolution at a time with a *grinding tool,* which is made like a carpenter's brace, only very much smaller. See *B, Fig. 69.*

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[1] Valves made of *tungsten steel* do not warp.

[2] You can buy a grinding paste ready made or you can make it by mixing some No. 120 emery with a little oil and thin it down with kerosene.

After you do this for a while wipe the paste from the valve and mark the beveled edge up and down with parallel lines with a very soft lead pencil, put the valve back in its seat and turn it to and fro again.

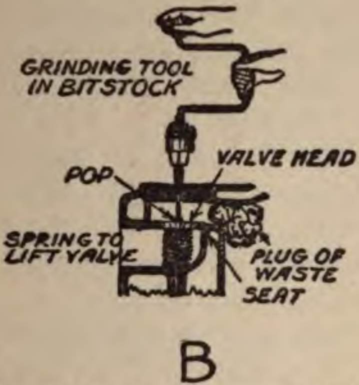

FIG. 69.—B. HOW TO GRIND A VALVE

If, now, all the pencil marks are rubbed out you will know that the valve and its seat are ground true, but if some of the marks still show keep on grinding the valve until it does seat right. When you are satisfied with the job clean off both the valve and the seat with gasoline and be sure that every particle of the paste has been removed.

When the Engine Begins to Knock.—*Where the Trouble Lies.*—There is an even dozen different diseases that make an engine knock, and, specified, these are (1) the spark is advanced too far; (2) it needs water, or lubricating oil, or both; (3) the spark-plugs need cleaning; (4) the compression is too high; (5) the bolts of the flywheel are loose.

(6) The fuel mixture is not proportioned right; (7) the bearings have too much play; (8) the piston or piston rings strike a ridge in the cylinder; (9) the clearance of the piston is too great; (10) there is carbon in the cylinder; (11) premature ignition caused by red-hot particles of carbon and (12) the piston head is too thin.

Locating and Removing the Cause.—The first thing to do is to (1) retard the spark by means of the spark control lever, and this will take the *noc* out of the knock if it was caused by the spark being advanced too far.

(2) The next best guess is that there is a lack of water in the cooling system, or a lack of oil in the crankcase or sump. If after supplying these essential liquids and making sure that the oil is feeding properly the engine keeps on knocking, then (3) try cleaning the spark-plugs.

Next (4) try the compression by opening the compression cock in the head of the cylinder a little; should you find that this eliminates the knock the remedy is to put in a *shim*[1] between the crankcase and the open end of the cylinder, so that there is more space between the piston and the head of the cylinder. This done, see (5) if the bolts of the flywheel are loose, and if so tighten them up.

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[1] A *shim* is a thin piece of metal used to widen the distance between two parts of a machine.

Then (6) change the proportions of the fuel mixture and try a *rich mixture,* that is, one in which there is a large amount of gas, gasoline or oil and a small quantity of air, and if this doesn't help matters reverse the proportions and try a lean mixture.

Look after (7) the bearings of the crankshaft and if these are loose take out one or more shims on each side and tighten up the bolts of the bearings. (8) Should there be a ridge in the cylinder the only remedy is to rebore the latter or put in a new one, and if there is too much piston clearance take out the piston and put in new piston rings.

When knocking is caused by (10) preignition due to incandescent carbon in the cylinder, or because (11) there is a deposit of carbon in the cylinder it must be cleaned out. To get out the carbon you must take off the cylinder head and remove the inlet and exhaust valve caps.

By turning the crankshaft over you can bring the piston to its inner dead center so that it will be close to the cylinder head and then you can scrape the carbon loose and into the exhaust passage. After you have removed all of the carbon in this way brush the valve heads and their seats clean so that none of the particles of carbon stick to them and then wash them with kerosene; finally (12) should the piston head be too thin the only way to effect a cure is to put in a new piston with a thicker head.

When the Engine Overheats.—*The Cause of the Disturbance.*—The chief reasons why an engine overheats are (1) that there is a lack of water; (2) the water pump may not be working right, or (3) the water pipes or the radiator may be clogged up.

(4) The oil may be of poor quality; (5) the spark may be retarded too much, or (6) if the engine is on a motor car the fan belt may be slipping; (7) the exhaust pot or the muffler may be choked up with soot; (8) the valves are not timed properly; (9) the fuel mixture is not properly proportioned; (10) the valves do not seat right; (11) the engine has not been *tuned up,* or *run in,* as it is called, and lastly (12) the radiator is too small for the engine.

How to Remedy the Defect.—When your engine gets too hot see that (1) there is a constant supply of cool water circulated between the jacket and the cylinder. If your engine has a hopper on it do not fill it more than ¾ full of water, because the water will splash out when it boils; on the other hand, never let the water get as low as the top of the cylinder, for then the latter will get too hot.

When the engine is working under a heavy load the water may boil, but this should not interfere with its proper working. Add water as it evaporates to keep it up to the right level. (2) Find out if the water pump is fouled and if so clean it out, and (3) also clean out the water pipes in the radiator, if the engine is a motor car one.

(4) Be sure the lubricating oil you use is of the best quality and that there is plenty of it; next (5) advance the spark, and (6) tighten the fan belt if it needs it. (7) The exhaust pot should be cleaned frequently, and even with mobile engines the muffler must be kept free from soot.

(8) To time the valves is a very particular job, especially if your engine has more than one cylinder, and unless you understand how to do it, you had better let some machinist who is an internal combustion engine expert time it for you.

In some stationary engines the inlet, or suction valve, is automatic in its action, and hence it needs no adjustment for timing. In engines of this kind, however, the exhaust valve should begin to open 30 to 35 degrees before the outer dead center of the crankshaft is reached.

The exhaust valve should close when the crank is about 5 degrees above the inner dead center.

To time the exhaust valve as above turn the crank over until it is in an upright position. Now adjust the exhaust valve rod so that there is about $\frac{1}{16}$ inch space between the end of it and the adjusting screw in the valve rocker arm. When you have done this the timing gears will set so that the exhaust valve will open and close as I have stated above.

Where the inlet valve is worked by a cam, as in all mobile engines, it must *lag,* that is, it must not open until just after the piston has made its exhaust stroke, and it must remain open, or lag, until the piston has made about $\frac{1}{3}$ of its compression stroke.

So that the burnt gases can be pushed out of the cylinder, or *scavenged,* to the best advantage the exhaust valve must *lead* a little, that is, it must open just before the power stroke is finished. Further, the exhaust valve when it is open must lag after the piston begins to make its suction stroke, so that every particle of the burnt gases can be scavenged and got out of the cylinder.

9) When the fuel mixture is not properly proportioned, try making a lean mixture, that is, cut down the amount of fuel for the quantity of air used.

Where a carburetor is employed to provide the fuel mixture if the latter is too rich at high speeds and when the load is light the cylinders will heat up unduly. To remedy this defect all you have to do is to cut down the amount of fuel or to adjust the butterfly valve in the main air inlet, or auxiliary air valve, until the fuel mixture is of the right quality.

(10) If the valves do not seat properly they must be ground, as I explained in paragraph *9* under the heading of *When the Engine Works Badly.* (11) An engine may overheat if it is new and has not been *run in,* but this should, of course, be done at the factory, and not at your expense. When you get such an engine, all you can do is to run it at a low rate of speed until it is tuned up.

(12) Finally, if the radiator is too small to keep

down the temperature of the water which circulates through it and the water spaces around the cylinder, the only remedy is to get a larger radiator and put it on.

First Aid to An Injured Engine.—There are a lot of little things that get the matter with internal combustion engines, and if you let them go they may develop into real troubles, and this is particularly true of small units.

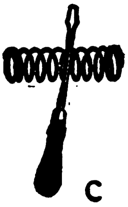

FIG. 69—C. STRETCHING A VALVE SPRING

Stretching Valve Springs.—If you find that your engine does not run as smoothly as you think it ought to, put the blade of a screw driver between the turns of the valve spring, as shown at *C* in *Fig. 69.* If this makes the engine run steadier or it picks up in power it shows that the spring needs stretching, so take it out and stretch it or, better, put in a new one.

Leaks and How to Stop Them.—A leak in a gasoline or an oil pipe if it is not too large can be stopped by putting a piece of common brown soap in the hole and then wrapping the pipe with a piece of electrician's tape or adhesive plaster tape. This is a first-aid repair and, of course, you must solder the leak as soon as you can.

If the water leaks at the joint where the flanges of the water pump and pipe are bolted together you can stop it temporarily by driving a thin, soft pine sliver into it, and this will last until you can put in a new gasket. If your engine is a mobile one and has a radiator on it you can stop a leak in it by plugging up the hole with a bit of chewing gum.

To stop a leak around a spark-plug either screw the plug in tighter, or if this does not do the trick put in a new one.

How to Clean Spark-plugs.—Dip an old tooth brush into some gasoline and scour off the points of the plug with it. If the deposit of carbon on them does not come off you will have to scrape it off with the blade of a knife or use a jeweler's file. When you have the points nice and bright wash them off with gasoline.

Cutting New Gaskets.—When making new gaskets use *asbestos packing* with a brass wire mesh[1] in it, for rubber packing will often rot or burn out when subjected to hot water and hot gases.

On Making Small Repairs.—Even if you are not mechanically inclined, when some small part breaks on your engine you can get a repair part from the maker and replace it yourself. By so doing you will not only save money, but you will get a better working knowledge of your engine, and this is decidedly the right thing to do.

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[1] This can be bought of the Johns-Manville Co., 41st St. and Madison Ave., New York City.

Every maker of good engines issues a price-list of parts, and as these are interchangeable you can send and get a replacement for any part of your engine, from the smallest screw on up to the base, and you can be morally certain that it will fit exactly when you get it.

About Making Big Repairs.—It isn't very often that anything goes wrong or breaks on a big engine, but if some part should, you can get a duplicate of it just the same. It may just be that you feel you are not competent to make the replacement, and if this is the case get a machinist at any shop and he will do it for you at a small cost.

Where a large part is broken, such as a connecting rod or a crankshaft, or a cylinder is cracked, you can have the parts welded together cheaper than you can buy the replacement.

Welding is done by three different processes, and these are (1) the *oxyacetylene,* (2) the *electric* and (3) the *thermit* processes. By writing to the following companies you can find the nearest shop to you which has one of their equipments and where the part can be welded. *The Prest-O-Lite Co.,* 206 Amsterdam Ave.; *Thompson Electric Welding Co.,* 30 East 42d St., and *Goldschmidt Thermit Co.,* 120 Broadway, all of New York City.

CHAPTER X

SCHEMES FOR POWER TRANSMISSION

Since an internal combustion engine cannot develop power until it is running at a certain speed it will not start on full load like a steam engine.

It is evident, then, that some sort of a device must be used to throw the load on gradually after the engine is running at its full working speed. There are three general schemes used for this purpose, and these are (1) the *tight and loose pulley,* (2) *friction wheels* and (3) *clutches.*

The Tight and Loose Pulley.—The simplest but far from being the best way to connect an engine with one or more machines is to put a *tight* and a *loose pulley,* see *Fig. 70,* on the machine and belt it either to the pulley of the engine direct or to a pulley on a line shaft which is driven by the engine.

When this arrangement is used, before you stop the engine you shift the belt onto the loose pulley. Now after you start the engine and it has gathered momentum enough you can gradually shift the belt from the loose pulley onto the tight pulley that is keyed on the driven shaft of the machine.

The Use of Friction Wheels.—*Wheels in Alignment.*—A simple and effective way for gradually transmitting the power of a small engine to a machine is by means of *friction wheels,* and, further, in some types of these wheels the speed of the machine can be varied within wide limits as the exigencies of the work may require.

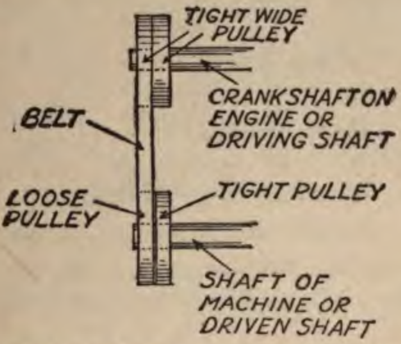
TIGHT WIDE PULLEY
CRANKSHAFT ON ENGINE OR DRIVING SHAFT
BELT
LOOSE PULLEY
TIGHT PULLEY
SHAFT OF MACHINE OR DRIVEN SHAFT

FIG. 70. THE BELT DRIVE. A TIGHT AND LOOSE PULLEY

All through this book I have preached the doctrine of lubrication, as this is the last step in reducing friction to a minimum in machinery, but while friction is a thing to be gotten rid of in engines it can be utilized to advantage when it is applied in the right way and one of these is in friction wheels.

In its simplest form a friction wheel transmission consists of two wheels whose outer faces, or *peripheries,* as they are called, set in the same plane, and which can be pressed together with more or less force, as shown at *A* in *Fig. 71.* The wheel which is connected with the crankshaft of the engine is called the *driving wheel* and the wheel fixed to the line or propeller shaft which it drives is called the *driven wheel,* and it is due to the friction, or *bite* as it is called, between their surfaces when in contact with each other that the first wheel makes the second one revolve.

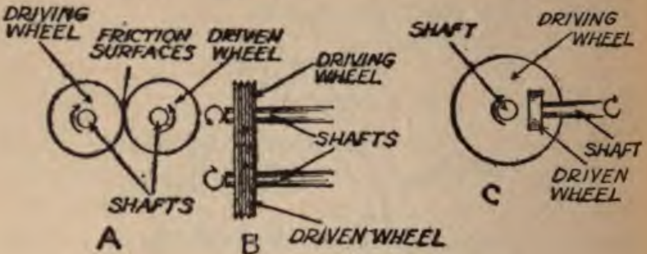

FIG. 71. FRICTION WHEEL DRIVES

A, Friction Drive with Wheels in Alignment. B, Friction Gear Drive. C, Friction Drive with Wheels at Right Angles.

To get the best tractive effort by means of this combination one wheel should have a smooth iron face and the other should be covered with leather or rubber. To make friction wheels of this type *bite* still better the faces of both wheels are often grooved, as shown at *B,* when they are called *friction gears.*

Although in friction wheels there is but a very small point of contact between them, yet it takes only a slight pressure to bring them together so that the driving wheel will transmit nearly all of its power to the driven wheel when the latter has been speeded up and, consequently, there will be very little slippage, but, of course, the action is not positive.

Wheels at Right Angles.—It is possible to do many things with friction wheels when they set at right angles to each other which could not be done with belted wheels or with *toothed gears,* as cog-wheels are sometimes called.

As an illustration, suppose you want to change the direction of the rotative power of the crankshaft of your engine at right angles with it, as shown at *C,* then all you have to do is to use a driving disk or wheel the side, or flat face of which is covered with leather and fix another wheel, or pulley on a shaft at right angles to and so that it will press on it.

Now, when the engine runs and you apply pressure to the friction wheels the power will be transmitted from the driving wheel to the driven wheel and the direction of the rotation will be changed 90 degrees; moreover, if you will fix the driven pulley on its shaft so that it can slide on and yet turn it[1] and then move it from the center of the driving wheel to its circumference, the speed of the driven wheel will be raised from 0 + to maximum.

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[1] This is done by using a *feather key* to secure the wheel and the shaft together. That is the shaft and the inside of the hub of the wheel have shots, called *keyways,* cut lengthwise in them; a straight key is fixed in the keyway of the wheel and when the latter is slipped over the shaft it makes a sliding fit in the keyway of it.

Further, if you shift the driven wheel across the center of the driving wheel from one side to the other the direction of rotation of the driven wheel will be reversed. This is the kind of a power transmission device that is installed in the Metz motor car for connecting the propeller shaft with the crankshaft of the engine, and by means of it the usual clutch arrangement and transmission gears are done away with and a variable change of speed is gained.

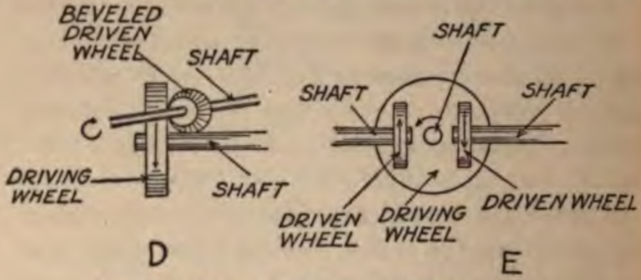

FIG. 71—D AND E. FRICTION WHEEL DRIVES

D, Friction Drive with Beveled Driven Wheel. E, Friction Drive with Driven Shafts in Alignment.

Finally, you can bevel the driven wheel, as shown at *D*, and in this way change its angle of rotation in relation to the rotation of the crankshaft, and make it revolve at whatever angle it may suit your purpose the best.

But setting another wheel on the opposite side of the driven pulley, as shown at *E*, with its face parallel with the face of the driving wheel and with its shaft in a line with the crankshaft, then the latter will rotate in the reverse direction to that of the driving wheel.

How Friction Clutches Work.—With friction wheels, as you have seen, both *elements,* as the driving and the driven wheels are called, rotate and it is the friction at their points of contact which prevents them from slipping.

Now, friction *clutches* differ from friction wheels in that after the *driven cone* or *disk,* which is fixed to the machine, is brought up to a speed as high as that of the *driving cone* or *disk* the former is forced hard against the latter, and they revolve in the same direction together, exactly as if they were a solid line of shafting.

Clutches for Mobile Engines.—In mobile engines such as are used on motor cars the friction clutch in one form or another is held in high favor among engineers as an easy and effective means for connecting and disconnecting the drive shaft with and from the crankshaft of the engine.

In fact, with the exception of the Metz car, which has the friction wheel drive described above, and the Owen car, which employs a *magnetic clutch,* to be described presently, all motor cars are provided with friction clutches.

There are two kinds of friction clutches designed especially for motor cars and these are (1) *cone clutches* and (2) *disk clutches.*

The Cone Clutch.—The cone clutch is formed of a leather-covered cone fixed to the end of the drive shaft and this is made to fit into a conical recessed member, that is, a cone-shaped hole in a piece of steel—usually the flywheel—and this is keyed to the crankshaft of the engine.

A strong, steel spiral spring forces and keeps the cone in the recessed member all the time except when it is pushed out by a lever worked by the foot of the driver who is running the car. The whole scheme is shown at *A* and *B in Fig. 72.*

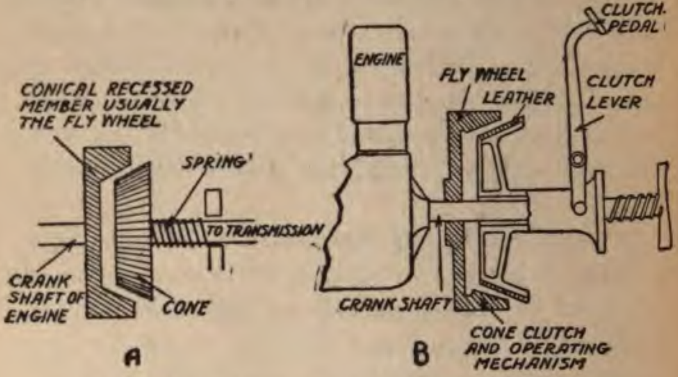

FIG. 72. THE MOTOR CAR FRICTION CONE CLUTCH

A.—Diagram of a simple Cone Clutch. B.—How a Motor Car Clutch is Made.

The Disk Friction Clutch.—In this type of clutch a number of thick, sheet steel disks, called the *driven disks,* are fixed on the drive shaft, and these interleave with an equal number of circular rings called the *driving disks,* which are mounted on the crankshaft of the engine.

A stiff, spiral spring holds the driven disks in close contact with the driving disks except when they are pushed out by the clutch pedal. Disk friction clutches for motor cars usually run in oil to keep them from wearing, but this does not prevent them from biting enough to make them hold rigidly together.

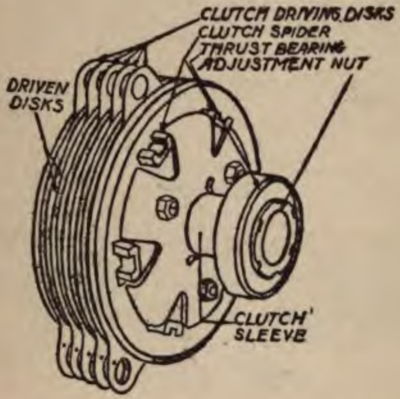

FIG. 73. A DISK CLUTCH FOR A MOTOR CAR

The Magnetic Clutch.—In this type of clutch magnetism is used instead of friction to grip the driving and driven shafts. The principle of the magnetic clutch will be understood from the drawing *Fig. 74*. Let a horseshoe magnet be mounted on the driving shaft and a round, soft iron core, or *armature,* as it is called, be mounted on the driven shaft so that they are free to revolve independently of each other.

Now if the soft iron core is placed between the poles of the magnet and the latter is rotated the iron core will be attracted to and pulled around with it in virtue of the magnetic lines of force that flow through them. To engage and disengage a magnetic clutch an *electromagnet* energized by a battery is used instead of the permanent one and the magnetic pull exerted by it on the iron core can be varied from 0 to a pull between them which is without slippage.

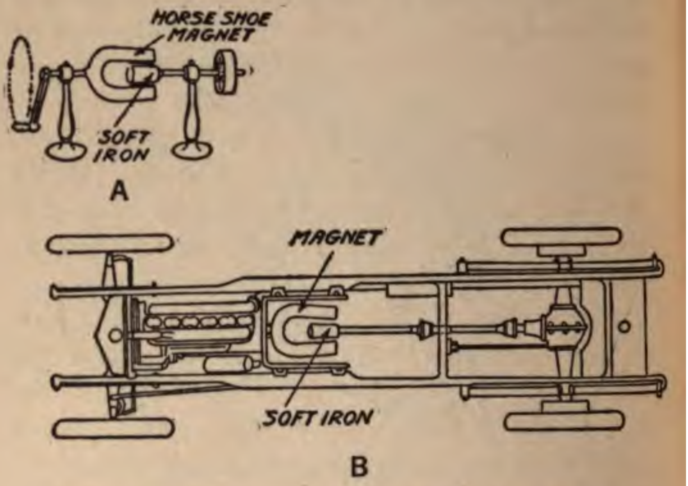

FIG. 74. A MAGNETIC CLUTCH FOR A MOTOR CAR

A, Principle of the Magnetic Clutch. B, Magnetic Clutch Schematically Shown on a Motor Car.

Clutches for Stationary Engines.—Two kinds of clutches are used for coupling up stationary engines to machinery and these are (1) *friction clutches* and (2) *magnetic clutches.*

Friction Clutches.—Clutches of this type can be divided broadly into two classes namely (1) *solid clutches* and (2) *split clutches.* These classes can be further divided into those (a) in which the pressure necessary to set up the friction is applied by hand, and (b) in which it is set up by the running of the engine.

How a Friction Clutch is Made.—A friction clutch consists of two chief parts and these are (1) the *shell half* and (2) the *mechanical half.* The shell and its hub is of cast iron and forms a perfectly smooth friction surface.

The mechanical half is made up of a driving plate on which an expansion ring is mounted, and this consists of two or more segments according to the size of the clutch. These segments can be forced apart or *expanded,* so that the *wood friction shoes,* which are bolted to them, are brought into contact with the inside of the shell by means of a right and left thread screw lever which run in nuts and which set in the opposed ends of the expansion ring and are held in position by a screw and shoe.

The right and left screw lever is worked by a powerful toggle which in turn is operated by a sliding sleeve. The combination of the right and left threaded screw makes a positive acting device of great power. At the outside end of the mechanical half is a *yoke* for securing the hand shifting lever to the sliding sleeve.

Finally, there is a balance weight to counterbalance the lever and toggle and this prevents the centrifugal force from throwing the clutch in gear when it is running at a high speed. A longitudinal cross-section of the clutch is shown at *A* in *Fig. 74,* a transverse cross-section of it is shown at *B,* and the clutch complete at *C.*

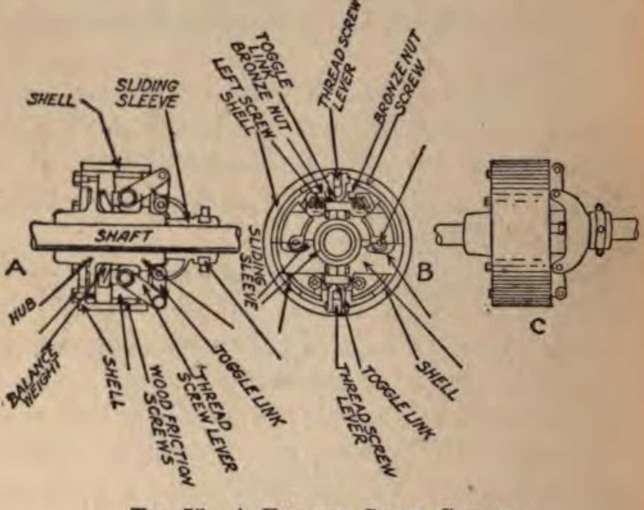

FIG. 75. A FRICTION SHAFT CLUTCH

A, A Lengthwise Cross Section View of the Clutch. B, Transverse Cross Section View of the Clutch. C, The Clutch on Adjacent Shafts.

For small engines the clutch, which is also used for a pulley, is worked by a hand wheel as shown at *A* in *Fig. 75,* but for larger engines it is operated by a lever, as shown at *B*.

Split Friction Clutches.—A *split friction clutch* is made in halves so that it can be put on the adjacent ends of the lengths of a line of shafting already in place, and can be readily installed without taking down the shaft or disturbing any of the equipment upon it. Then again, it affords the greatest ease in taking off old parts and putting in new parts should any repairs or renewals be necessary.[1]

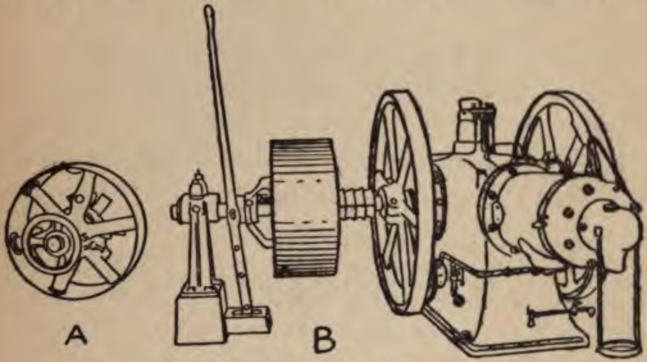

FIG. 76. FLYWHEEL CLUTCHES

A, Flywheel Hand Type of Friction Clutch. B, Flywheel Lever Type of Friction Clutch.

Magnetic Clutches.—This type of clutch is constructed on the same general principle as the one described for mobile engines. It is chiefly used for stationary power installations where electric generators or converters are to be started up and which must not too greatly disturb the load.[1]

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[1] For friction clutches of this type write A. & F. Brown, 79 Barclay Street, New York.

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[1] For magnetic clutches write Cutler-Hammer Clutch Co., Milwaukee, Wis.

CHAPTER XI

THE KIND OF AN ENGINE YOU WANT

There are many makes of internal combustion engines on the market and the kind you want will depend very largely on what you intend to use it for and the conditions under which you are going to run it.

There are, however, a few considerations in buying an engine that are fundamental and which if you are looking for service and economy at the same time you ought to know about, for if you buy one haphazard of the first make you come across you will stand a very slim show indeed of getting a good one at a fair price.

Small versus Large Concerns.—Far be it from me to want to *knock* the small manufacturer but to buy the best gas engine that can be made and get a guarantee that is backed up by something that looks like real responsibility you have simply got to buy an engine of a big maker or of a house of recognized financial standing.

When you buy an engine of such a concern and anything goes wrong with it you will have far less trouble in getting the dealer to *make good* in adjusting the matter. Not only this but all up-to-date engines are built on the interchangeable plan, as I have mentioned before, and if you are dealing with a big company you can get a repair part in the shortest possible time because they always keep a large stock of replacements on hand.

Further, all big concerns have branch offices in many of the larger cities in the United States and so wherever you live you will have one of these service stations close at hand and this is a very great convenience. Finally, a lot of the smaller makers come and go and if you have one of their engines and they go out of business the only way you can get a repair part is to have it made to order, and this will sometimes run your replacement part into big money.

And another thing, don't make the mistake of buying an engine of some obscure maker because you can get it a deal cheaper than you can get one of the same horsepower of a well-known maker. If big concerns charge more for their engines you can depend on it that a good engine built to stand the test of time and the stress of duty simply can't be built for a lower price. Shoddy costs less in the beginning, but it can't compete with wool for wearing qualities.

Finally, every large manufacturer maintains an experimental laboratory where all new devices are tested out by experts before they are ever put on the engines they sell.

In order to buy a cheap make of engine second hand and get your money's worth you must be able to do, as the magician says, possible impossibilities, and that is to perform to a nicety the operation that is called in mathematics *the calculus of probability* which in turn means the calculation of the likelihood of events.

Then after you have found the product, looked over the machine, paid the purchase price and installed it you will be the better able to bear up with fortitude if anything goes wrong with it.

But if you can buy a good make of second-hand engine like the Otto, or Bessemer or De La Verne of a reputable dealer who may occasionally have such a one that he has taken in part payment for a new one of greater power you will not only be satisfied with it, but you will save a lot of money in its initial cost and in its upkeep as well.

Vertical versus Horizontal Engines.—Where your floor space is at a premium the vertical type of engine is, of course, the one to use and hence this applies to all motorcycle, motor car, marine and airplane engines and very often to stationary engines, as well.

Not only is floor-space a factor in choosing between the vertical and horizontal types of engines, but since the crankshaft of the former sets close to the bottom of the frame it puts it in exactly the right place to couple it up with the propeller shaft of the cycle, car, boat or plane.

In very small stationary engines it does not matter much whether it is vertical or horizontal, unless the crankshaft of the engine is to be coupled direct to the armature shaft of a dynamo when the design of the former makes it somewhat easier to connect up and perhaps a bit steadier when it runs.

A little horizontal engine is easier to cool than a vertical engine for the reason that a water hopper can be mounted directly on top of it, and where an engine is to be belted to a dynamo or other machine a horizontal engine is perhaps a trifle more rigid than a vertical engine.

Nearly all large engines except those built for the marine service are made horizontal because they are easier to build, to set up, to get at, are more rigid, and, hence, there is less vibration.

Two Stroke Cycle versus Four Stroke Cycle Engines.—All motorcycle, motor car and airplane engines are made on the four stroke cycle principle, while marine and stationary engines are made on both the two and four stroke cycle principles.

Two stroke cycle engines in one and two cylinder types run a little smoother than those of the four stroke cycle types having the same number of cylinders, because in the former there is a power stroke to every revolution of the crankshaft while in the latter there is a power stroke to every two revolutions.

In virtue of the fact that the fuel mixture in a two stroke cycle cylinder, especially in engines of the smaller sizes, is always contaminated by the burnt gases it is harder to start a two stroke cycle engine than it is a four stroke cycle engine of like size. If the engine is a large one and has a self-starter, this difficulty need not concern you.

Because there is an explosion to every revolution of the flywheel two stroke cycle engines are smaller and weigh less since the power is delivered every other stroke instead of every fourth stroke and consequently the flywheel can be made some lighter. On the other hand a two stroke cycle engine heats up more than one having a four stroke cycle, and it takes therefore more water to cool it. But this is of no importance if it is to be used for driving a motor boat.

Single Cylinder versus Multicylinder Engines.—It is a well known fact in engine calculation that the fuel economy rapidly increases with the size of the cylinder. Since this is true it stands to reason that a single cylinder engine is always the most economical not only in its first cost but in its operation as well.

A single cylinder engine is more simple to manage and you should always use it for stationary work if you can possibly do so. But when the size of the cylinder reaches a certain critical point it cannot be easily increased and so where more than 75 or 100 horsepower is needed it is the better practice to install an engine having two or more cylinders.

The Size of an Engine in Relation to Its Fuel Economy.—The fuel economy always raises with the load but in an engine of good design it will remain pretty nearly the same from three-quarters load on up to full load.

For this reason it is not good practice to buy a 2 or 3 horsepower engine if a 1 horsepower engine will give you all the power you need. Not only is the fuel economy greater when the engine is running on full load but it uses less lubricating oil.

While all reputable engines are built to carry overloads still it is bad policy to install too small an engine, for it will have to bear the brunt of extra wear and tear due to excessive stress and strains and these will be sure to cost you dearly before the end.

The Type of an Engine in Relation to the Fuel Available. From what has gone before you will get a pretty clear idea of whether you want a vertical or a horizontal engine, one that works on a two or a four stroke cycle, and the size you need, and now comes the question of the kind of fuel that you must burn in your engine.

In districts where *natural gas* can be had or where *illuminating gas* can be bought at a low cost these are the ideal fuels, but for engines of from 40 to 300 horsepower *producer gas* will be found the most economical.

Gasoline is the kind of *liquid* fuel to use where high speeds and certainty of operation, as in mobile engines, are required and economy is not of the greatest importance. In small engines, such as are used on the farm where a cheaper fuel is preferable, an oil engine using a low grade of kerosene is the kind to get.

Crude fuel oils are not to be recommended for very small engines but where you can get this fuel cheaply and where high economy must be practiced, if you can use an engine large enough to burn them successfully, by all means do so.

Electric versus Other Ignition Systems.—Engines that burn gas or gasoline can be operated best by some kind of an electric ignition system.

A *wipe spark* gives the best results when used with large gas and gasoline engines, since neither the speed nor the compression is very high.

Where a *jump-spark* system is employed in which the spark is set up by a battery and a spark coil, dry cells will not stand up long under the strain, and if possible you should put in a storage battery, or, better, a magneto.

For a motor boat or a small stationary engine a dry battery will serve in a pinch for energizing the spark coil, but the engine will never deliver its full power when it is used.

Nearly all motor cars and many motor boat engines are equipped with a *circuit breaker spark-coil system,* or *distributor system,* as it is called; in this ignition apparatus a storage battery is used to energize the spark coil, but the better makes of mobile engines are also fitted with a high tension magneto and this gives a good hot spark.

A *magneto* is far less troublesome on stationary engines than any kind of a battery operated spark-coil system, but while its initial cost is higher, it is well worth the difference in the price. On hand-started gas and gasoline engines an *oscillating magneto* is better than a rotating one, because the armature of the former is only turned through a very small *arc* past the poles of the magnet by a pair of stiff springs, and, consequently, it delivers a hot spark the first time you turn the flywheel over. Oscillator magnetos are not suitable for high-speed mobile engines, but on medium-sized stationary engines they give very satisfactory results.

Where crude oils furnish the fuel a semi-Diesel engine, that is, one fitted with a hot ball, or bonnet, or a straight Diesel engine, in which the charge ignites automatically, is the proper kind to get, for it takes a very hot cylinder to change these fuels into gases that will burn and not leave behind a residue.

Kinds of Lubricating Systems.—In small stationary engines a simple oil-cup drip feed can be used, but a splash lubricating system will give better service, while in larger engines the best results are obtained by the force feed system.

How to Use the Power of Your Engine.—*The Mechanical Way.*—In motorcycles, motor cars, motor boats, and airplanes the engines drive the propeller shafts either through clutches and transmission gears, through clutches alone, or by being directly connected, and that is all there is to it, as far as you are concerned. But on the farm, things are very different, for there may be a dozen distinct machines you want to drive with your engine.

Again, occasionally, you may want to use your engine in any one of a number of places and under various conditions, and you must think about all these details before you invest your money in one. Where an engine is to be moved about it can be set on a skid if it is a small one, or it can be mounted on wheels, as shown in *Fig. 36,* if it is too heavy for two men to carry about.

Where machines such as corn-shellers, circular saws for sawing wood, pumps, cream separators, lathes, grind-stones and the like are to be run by a stationary engine, the pulley of each one can be of such a size that it can be belted to the engine when you want to use it, though for some machines a *countershaft* will have to be used to decrease or increase the speed that is required.

When a number of machines are to be thus run by an engine it will save time, trouble and expense to fit up a regular shop and use a line of shafting so that any machine can be shifted in or out of gear, or two or more machines can be operated at the same time.

The Electrical Way.—If your engine is to be used to drive a dynamo for generating an electric current, the crankshaft can either be coupled direct with the armature shaft or the engine can be belted to the dynamo, just as it is with any other machine.

Now, an electric current generated by a dynamo is useful in the house and on the farm in three distinct and wholly different ways, and these are (1) for *lighting,* (2) for *heating,* and (3) for *power.*

None of the very small single cylinder engines that are now marketed have close enough regulation, that is, they do not run steady enough, to drive a dynamo so that the current can be taken off directly from the latter and used for lighting incandescent lamps.

To do this successfully a storage battery must be connected to the dynamo and charged by it and then the current can be used from the battery and lamps which are lighted by it will not flicker.

A large single cylinder engine which uses either gas, gasoline or oil can, if it is fitted with a good governor, be employed to run a dynamo, and the current generated by it be used for lighting without the intervention of a storage battery.

Where an engine drives a dynamo for lighting and a storage battery is not installed the plant must, of course, be kept running all the time the lights are on. But where a storage battery absorbs the electric energy from the dynamo and then gives it up to light the lamps, the engine can be shut down and the current supplied entirely by the storage battery.

Further, if you want to light more lamps than either the dynamo or the storage battery can singly generate or deliver enough current for, you can carry the *peak load* by driving the dynamo and using the current from it and the storage battery at the same time.

When the current from a dynamo is used only for heating and power purposes the regulation of the engine need not be anywhere nearly as close as for lighting. Small portable electric motors can be bought, and with these you can do nearly any kind of work anywhere by simply *plugging* into an electric light socket.

CHAPTER XII

USEFUL INFORMATION

Fire Underwriters' Rules for Installing and Using Internal Combustion Engines. Installing Gas Engines.—(1) *Location of Engines.* (a) The engine should, wherever possible, be located on the ground floor.

(b) In workshops or rooms where dust or inflammable flyings prevail, the engine should be enclosed in a suitable compartment, well ventilated to the outer air at floor and ceiling.

(c) If the engine is located on a wooden floor, the floor under it and for 24 inches outside of it should be covered with metal.

(2) *Piping.*—(a) This must be provided with a shut-off valve located in an accessible place on the service side of the pressure regulator.

(b) Piping and connections must be run as direct as possible, and be thoroughly tested before being placed in service.

(3) *Igniter or Exploder.*—Electric ignition only must be used. Hot tubes and any provision for their installation on engines are prohibited.

(4) *Muffler or Exhaust Pot.*—(a) Exhaust pots

must be placed on firm foundations, and mufflers and exhaust pots are to be kept at least one foot from woodwork or combustible materials.

(b) Exhaust pots of the closed type must be provided with plugged opening, placed near the bottom and below the exhaust pipe connection.

(5) *Gas Bag or Pressure Regulator.*—(a) Gas bags, if used, must be enclosed in a substantial airtight drum, of approved construction, vented to the outer air through a pipe used for no other purpose.

(b) Where it is not otherwise provided for, the regulator should be arranged with an automatic gas shut-off to prevent the flow of gas into the room in case the engine shuts down from any cause.

(6) *The Exhaust Pipe.*—This pipe, whether direct from engine, or from mufflers, shall, where practicable, be carried above the roof of the building in which the engine is contained and above adjoining buildings. When buildings are too high to make this practicable, the pipe shall end at least 10 feet from any wall opening.

No exhaust pipe must be within 9 inches of any wooden lath and plaster partition, ceiling, or other combustible material. Where exhaust pipes pass through combustible partitions they shall be guarded by galvanized iron ventilated thimbles at least 12 inches larger in diameter than the pipes, or by galvanized iron thimbles built in at least 8 inches of brickwork or other non-combustible material.

Exhaust pipes must not, under any circumstances, be connected into chimneys or flues, except that the pipe may pass up in flues which are used for no other purpose. No exhaust pipe shall pass through any floor, nor through a roof having wooden framework or covering.

As the pipe is apt to become very hot it should have additional protection where dust or inflammable flyings are present.

(7) *The Engine Base.*—It is recommended that the base be constructed with a groove or channel to prevent lubricating oil from sucking into floors.

(8) *Lubricating Oil Drips and Pans.*—(a) These must be provided to prevent the oil from spilling.

(b) Cranks and other rapidly revolving or reciprocating parts must be shielded to prevent throwing of oil.

(9) *About Name Plates.*—A name plate giving the name of the manufacturer and the trade name of the engine must be secured to the engine.

(10) *Care and Attendance.*—Due consideration must be given to the cleaning of the cylinders, valves and exhaust pipe and pot as often as the quality of the fuel may necessitate.

Installing Stationary Gasoline Engines.—(11) *Location of Engines.*—This is the same as for gas engines, as described under the heading 1 and in paragraphs a, b, and c.

(12) *Capacity and Location of Tanks.*—In closely built districts, or within fire limits, tanks should be located underground to conform to *Class B* of Regu-

lations for Construction and Installation of Containers for Storing and Handling Hazardous Liquids. You can get a copy of this booklet free of charge by writing to the *National Board of Fire Underwriters,* William Street, New York.

(13) *Gasoline Feed-Cup.*—(a) This must be arranged to prevent spattering, dripping or the exposure of gasoline either when the engine is at rest or running.

(b) It must also be provided with an overflow connection which drains back to the supply tank.

(14) *Gasoline Feed Pump.*—This must be of approved type, secure against leaks with check valves placed as close to the pump as convenient.

(15) *Igniter or Exploder.*—Electric ignition only, and the same conditions apply in other respects as for gas engines, as described under heading *3.*

(16) *Muffler or Exhaust Pot.*—Same as for gas engines, as described under heading *4,* in paragraphs *a* and *b.*

(17) *The Exhaust Pipe.*—Same as for gas engines, as described under heading *6.* Water pockets in the exhaust pipe must be provided with suitable means for drainage.

(18) *The Engine Base.*—(a) It must not be used as a storage space for gasoline or other materials.

(b) See also heading 7.

(19) *Lubricating Oil Drips and Pans.*—See heading *8,* paragraphs *a* and *b.*

(20) *Name Plate.*—See heading *9.*

(21) *Care and Attendance.*—See heading *10.*

Portable Gasoline Engines.—Under this heading are included the so-called self-contained engines, mounted on skids or wheels, or otherwise so arranged as to be conveniently moved from place to place as the necessities of the service may demand.

These engines are considered more hazardous than stationary engines having separate underground storage tanks, and should not be used as a substitute for stationary engines. When used, their hazards are recognized by the inspection department of the *Underwriters,* having jurisdiction, and, hence, the following rules and precautions should be rigidly observed:

(22) *The Supply Tank.*—(a) Gravity feed from a supply tank to the engine is prohibited.

(b) The capacity of the supply tank must not exceed the amount of fuel required for 10 hours' running, full load.

(c) The tank must be so mounted as to be protected against wear due to jarring and vibrations.

(d) It must be so located, or protected, as to avoid injury from coming in contact with outside objects, as well as to prevent an excessive use of temperature of the gasoline due to the heat from the cylinder or exhaust.

(23) *Piping and Fittings.*—See heading *12.*

(24) *Gasoline Feed Cup.*—See heading *13.*

(25) *Gasoline Feed Pump.*—See heading *14.*

(26) *Igniter or Exploder.*—See heading *3.*

(27) *Muffler or Exhaust Pot.*—See heading *4*, paragraph *b*.

(28) *Lubricating Oil Drips and Pans.*—See heading *8*.

(29) *Name Plate.*—See heading *9*.

(30) *Care and Attendance.*—(a) The supply tank should be filled during daylight hours only, and while the engine is not running.

(b) The tank should be filled by means of approved safety cans, and main gasoline supply should be kept in approved receptacles outside of buildings.

(c) Due consideration must be given to the cleaning of the cylinder, valves and exhaust pipe as often as the quality of the fuel may necessitate.

(d) Portable engines should not be used where dust or inflammable flyings prevail, nor be located near combustible material.

Stationary Kerosene and Fuel Oil Engines.—The following regulations refer to engines using a fuel having a flash point above 100 degrees *Fahrenheit*:

(31) *Location of the Engine.*—Same as for gas engines, described under heading *1*, in paragraphs *a*, *b*, and *c*.

(32) *Capacity and Location of Tanks.*—These should conform to the Regulations for the Storage and Use of Fuel Oil in *Class A*, and under the heading of *11* to *16*, inclusive, of *Class B*. A copy of these rules will be sent you free of charge by the *National Board of Fire-Underwriters.*

(33) *Fill and Vent Pipes.*—See heading *12*.

(34) *Auxiliary Tanks.*—(a) Tanks or other reservoirs for providing a supply of oil inside of the building must have a capacity of not more than 60 gallons when not of the pressure type. Such tanks must be filled by means of an approved pump, which is connected by full weight iron or steel pipe to the main supply tank.

The auxiliary tanks must be provided with an ample overflow pipe connected with the main supply tank. The oil must be drawn from the auxiliary supply by means of an approved pump worked by the engine. Feeding oil by gravity to the engine or pipe connections below the oil level in auxiliary tanks which have a capacity in excess of one gallon is not to be permitted.

(b) Tanks or receivers of the pressure type must not have a capacity of over 10 gallons, and must be provided with a reliable gauge. This tank must also have an approved pressure relief set to operate at a safe pressure and connected by an overflow pipe to the main tank.

These receivers when arranged with engine supply pipe connections below the oil level, to be so arranged that the oil will automatically drain back to the main supply tank when the engine stops, leaving not over 1 gallon when necessary for priming. In case the supply of oil for the engine by piping is connected above the oil level the automatic release of the pressure without the draining of the oil may be permitted.

(35) *Piping.*—See heading *12.*

(36) *Ignition and Starting.*—(a) Torches for pre-heating the combustion chamber of engines are to be used only while starting the engine, and the pressure on the supply reservoir is to be released as soon as the engine is *firing* properly.

(b) Torches used for initially heating the combustion chamber must be of a type approved for use with kerosene.

(c) Gasoline, if used for starting engines, must be introduced as a fuel inside the cylinders and the supply of gasoline must not be more than necessary to produce a proper temperature for operating the engine with the heavier fuel oils.

(d) The gasoline supply for engines using this liquid for starting must be drawn from an outside underground storage tank by means of a hand pump permanently attached to the engine in an approved feed cup or reservoir having a capacity of not more than 1 pint and provided with an overflow to the outside gasoline tank; or an approved reservoir of the *lift out* type may be used, provided the capacity is limited, as explained in paragraph *c,* above, but it must not exceed 1 gallon, and, further, that the retention of any gasoline after the engine starts is automatically prevented.

(37) *The Muffler or Exhaust Pot.*—Same as described under heading *4.*

(38) *The Exhaust Pipe.*—Same as described un-

der heading *6*. Water pockets in exhaust pipes to be provided with suitable means for drainage.

(39) *The Engine Room.*—Same as described under heading *7*.

(40) *Lubricating Oil Drips and Pans.*—Same as described under heading *8*.

(41) *Name Plate.*—Same as described under heading *9*.

(42) *Care and Attention.*—Same as described under heading *10*.

(1)

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